The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

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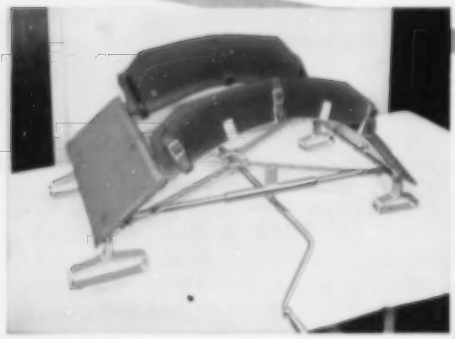

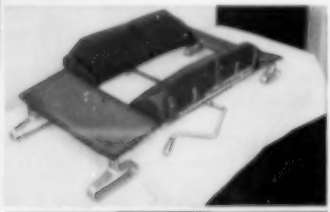

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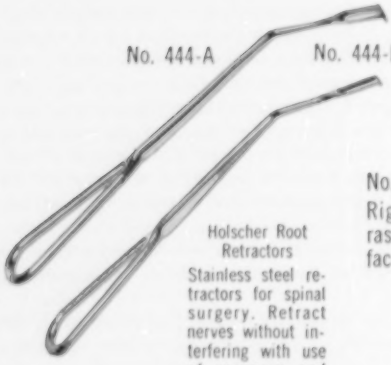

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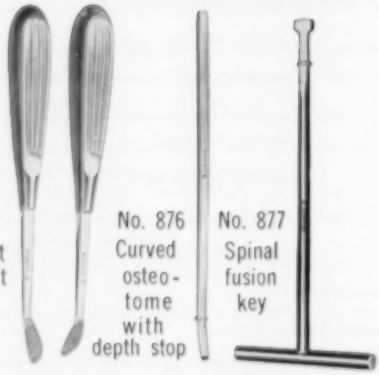

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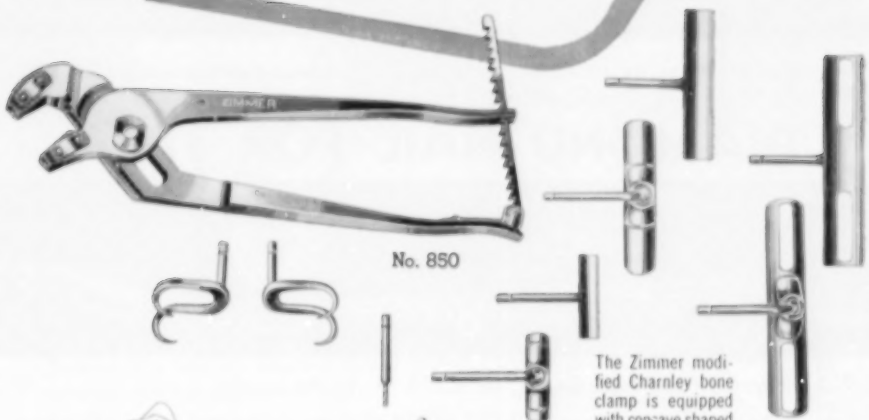

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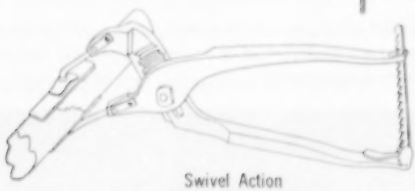

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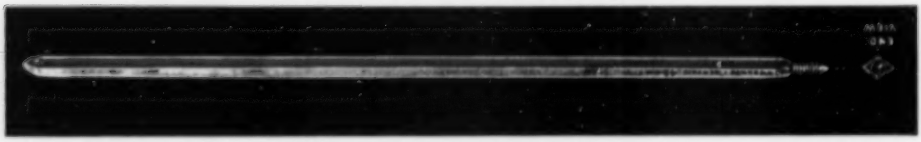

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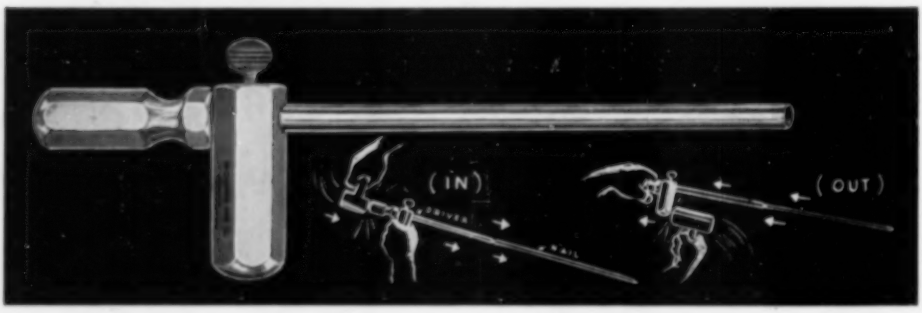

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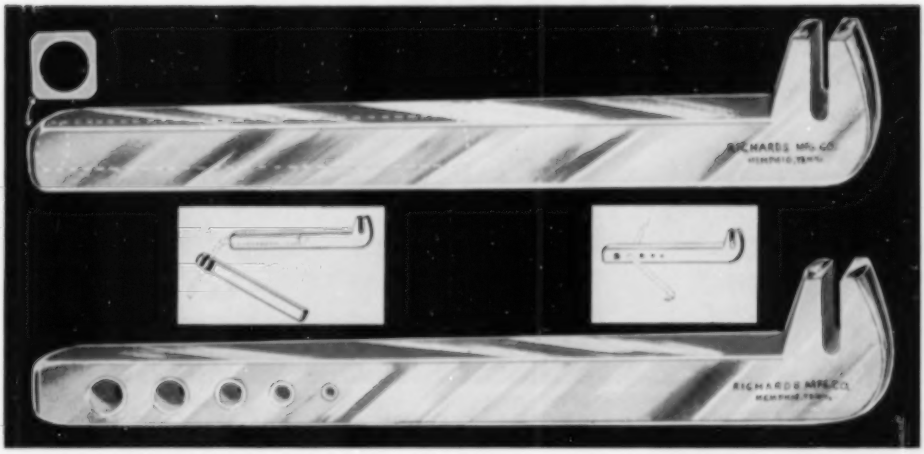

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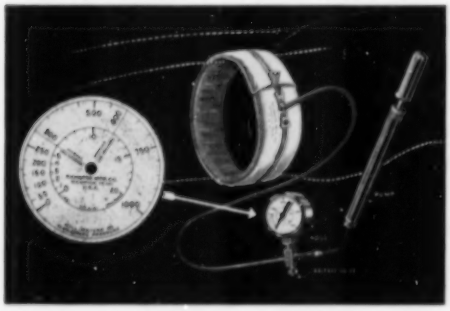

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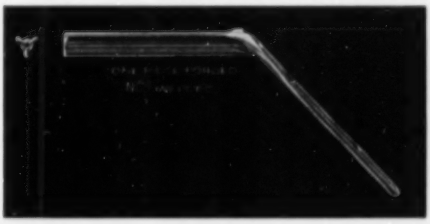

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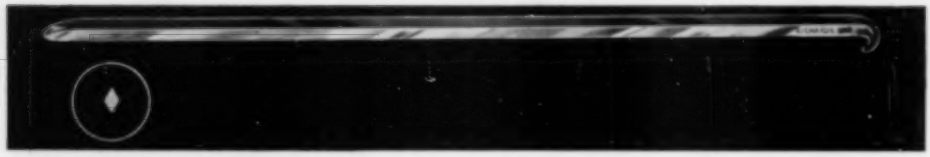

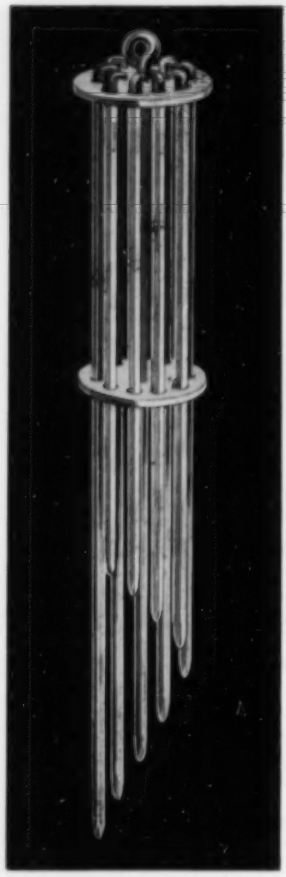

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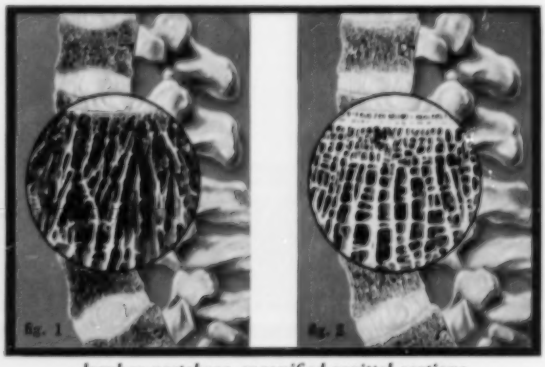

lumbar vertebrae, magnified sagittal sections

The vital role that estrogen and androgen play in the preparation and recalcification of bone matrix readily explains why declining sex hormone production which accompanies aging is most frequently the cause of osteoporosis. Note typical atrophic changes characteristic of postmenopausal osteoporosis (fig. 1) in contrast to normal bone matrix (fig. 2). Reifenstein* is of the opinion that some degree of osteoporosis is almost "physiologic" after the menopause, and that clinical osteoporosis may be found in about 10 per cent of women over 50 years of age.

With combined estrogen-androgen therapy, "pain in the spine and other bones is relieved considerably or completely in a matter of weeks to months," and with extended periods of treatment, the prognosis for bone recalcification is good.*

Combining both estrogen and androgen, "Premarin" with Methyltestosterone provides a dual approach for maximum efficiency in treating osteoporosis. A brochure outlining full details of therapy is available at your request.

*Reifenstein, E. C., Jr., in Harrison, T. R.: Principles of Internal Medicine, Philadelphia, The Blakiston Company, 1950, p. 655.

"Premarin" with Methyltestosterone is supplied in two potencies: the *yellow* tablet (No. 879) contains 1.25 mg. of conjugated estrogens equine and 10 mg. of methyltestosterone; the *red* tablet (No. 878) contains 0.625 mg. and 5 mg. respectively. Both potencies are available in bottles of 100 and 1,000 tablets.

"PREMARIN"® with METHYLTESTOSTERONE Ayerst

for combined estrogen-androgen therapy

New York, N. Y., Montreal, Canada

NEW

Davis & Geck's Spiral Wound Surgical Gut on a cylindrical reel!

Saves time makes easier ties

Surgeons welcome a new convenience—D & G Spiral Wound Surgical Gut. It is wound on a cylindrical reel—comes *ready for immediate use* in ligation and suturing. Spiral winding preserves all the original strength. None is lost through kinks or bends.

Nurses, too, save time with Spiral Wound Gut. No more unwinding from an old style flat reel and re-winding onto a rubber tube, glass rod or spindle.

For surer hand ties

When the surgeon makes a series of hand ties, D & G Spiral Wound Surgical Gut USP unreels in his hand, free from kinks, with all its tensile strength preserved.

The gut should be gently pulled out straight immediately after removal from the tube.

D & G foresees the surgeon's needs

D & G Spiral Wound Gut is the latest Davis & Geck contribution to improved suturing. "Timed-absorption" surgical gut is another—this exclusive D & G method embodies accurately graded degrees of chromicizing. The suture resists digestion most strongly during the first postoperative days, when greatest strength is needed. It is absorbed more rapidly when tissues have regained their natural strength.

Davis & Geck, Inc.
A unit of American Cyanamid Company
Danbury, Conn.

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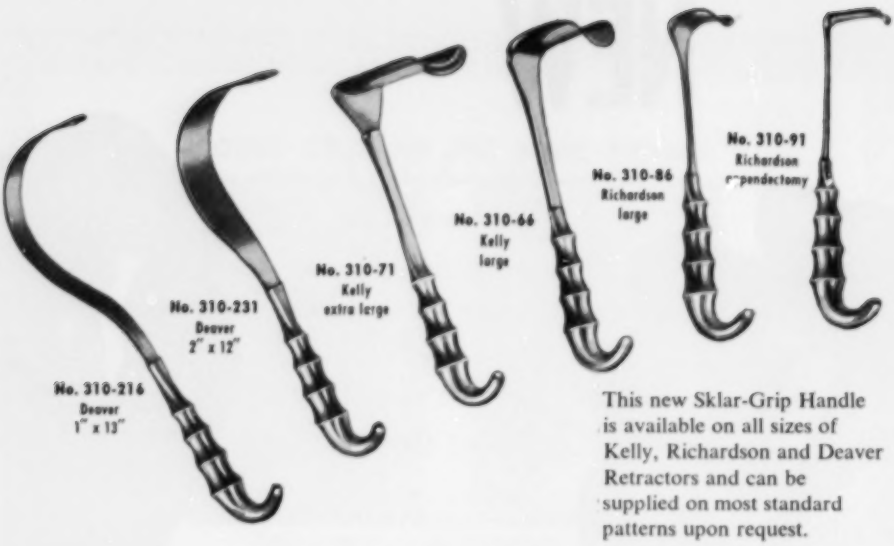


This new Sklar-Grip Handle is available on all sizes of Kelly, Richardson and Deaver Retractors and can be supplied on most standard patterns upon request.

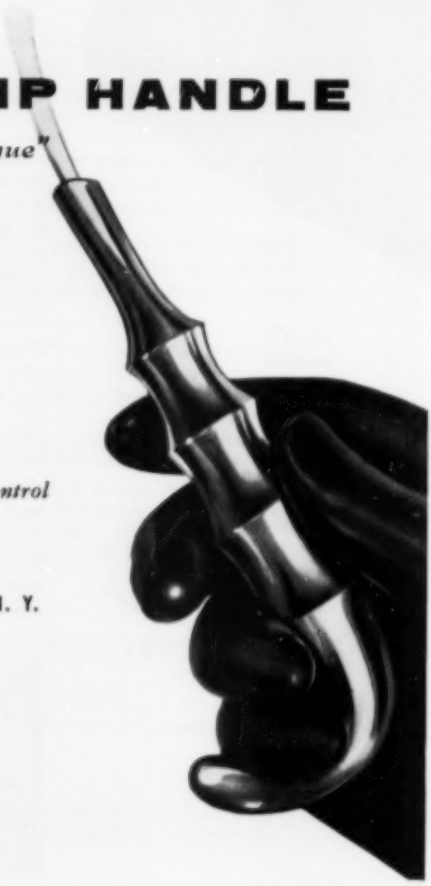
New...

SKLAR-GRIP HANDLE

Answer to "Retractor Fatigue"

The new Sklar-Grip follows the contour of any hand. This modification assures exceptional comfort and control during any surgical maneuver, particularly where prolonged retraction is indicated.

The Sklar-Grip Handle . . .
Easy to hold . . .
A new experience in balance and control



Sklar LONG ISLAND CITY, N. Y.

CAUTION: If the name SKLAR is not stamped on the instrument it is not a genuine Sklar Product.

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WEBRIL® Promotes Skin Hygiene Protects Against Pressure Sores

Unlike conventional cast padding materials, Webril bandage, a *Curity* product, absorbs perspiration and skin exudate. Protects against chafing, and promotes better skin condition throughout immobilization period. Conformable and cohesive, Webril is easy to apply—needs no adhesive or other bandage for anchoring.

New Plaster Bandage Handles Like Velvet

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A real pleasure to work with, new OSTIC gives you that high quality "creamy feel" you want for smooth workability—but without sacrifice of fast wet-out, cast strength and controlled setting qualities.

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Every genuine Rush Medullary Pin that has ever been made was made by *Berivon*

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P.O. BOX 1851
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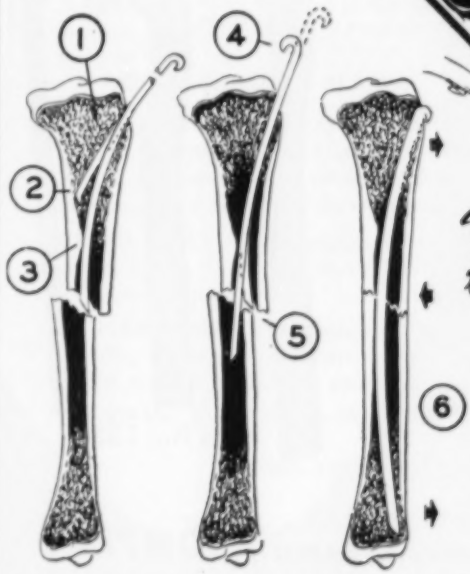
(PATENTED)

Drives like a Toboggan



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1. TO DRIVE THROUGH CANCELLOUS BONE
2. TO GUIDE PIN DOWN MEDULLARY CAVITY
3. TO SLIDE OVER OBSTRUCTIONS
4. TO ROTATE HEAD ROTATES POINT
5. TO GUIDE BY PIN ROTATION
6. TO CONTROL BONE ROTATION BY POINT PRESSURE

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NYLON equipped braces are available in both steel and aluminum, in drop-lock, free-lock and french-lock types.

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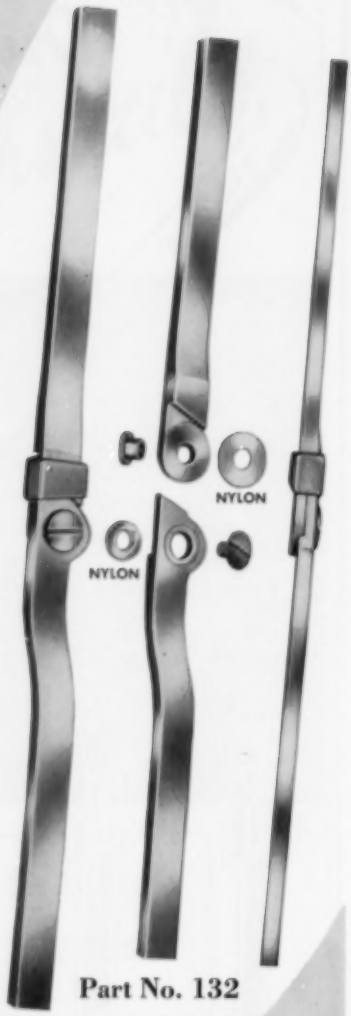

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QUALITY USMC

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UNITED STATES *Manufacturing* COMPANY

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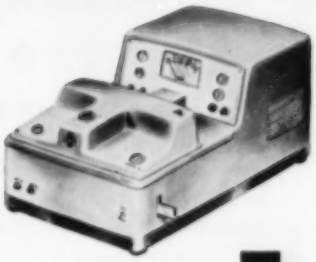
Guarantees **A·S·R BLADES**

THE SHARPEST EVER MADE!



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EDGE-FINENESS determines perfect cutting qualities. Sharpometer Edge-Fineness tests enable A. S. R. to ***guarantee*** . . . precise, uniform sharpness and dependability for every single blade!

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A strong, one-piece appliance that has proven very popular.
Vitallium prostheses excel as femoral head replacements because they are completely tolerated by human bone and tissue. First used in 1939, Vitallium hip prostheses have proven their strength, durability, and inertness through many years of clinical use.

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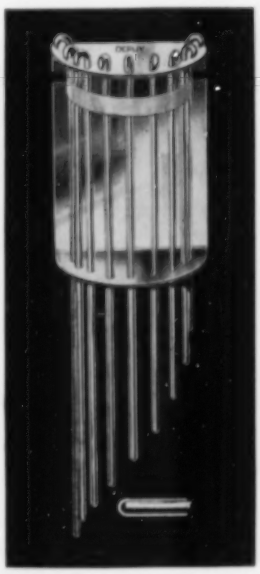
. . . help you Set Fractures



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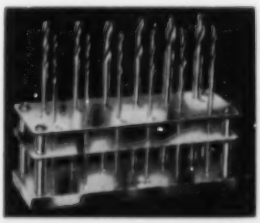

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With Rounded Tip, No Sharp Point

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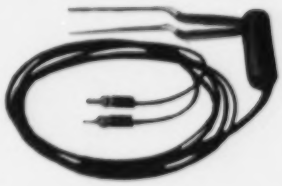
Does the work of an instrument costing hundreds of dollars by using the electrical equipment you have.



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Dial the screw you need by turning the cylinder. Entire unit is sterilized. Sterile screws can be removed without touching. New smaller compact unit or large model available.

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NEUTRILIUM® is the most non-corrosive metal known to science. Its proven super-strength lends an assurance of permanence to internal fixation of the trochanteric area. This neutral, non-magnetic, homogenetic alloy is entirely inert and therefore compatible with human bone or tissue, remaining unaffected by body chemistry.

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GENUINE NEUFELD NAILS and SCREWS — of ***NEUTRILIUM®*** — made only by MEDICAL RESEARCH SPECIALTIES, Loma Linda, California, are sold nationally by leading surgical and orthopaedic supply dealers.

NEUTRILIUM® *is a registered Trade Name of Medical Research Specialties.*

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Used for internal fixation of intertrochanteric and subtrochanteric fractures.
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HYDROCHLORIDE 2%
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PREFERRED local anesthesia
Xylocaine® Hydrochloride (Astra) merits special consideration by the busy anesthesiologist and surgeon. Profound in depth and extensive in spread, its well-tolerated effect is more significantly measured by the time saved through its remarkably fast action, by which so much normally wasted "waiting time" is converted to productive "working time".
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AN AQUEOUS SOLUTION
A 4th dimensional approach
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No. 1004-100.

Large sectioned blade
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presents a Combination Bone Saw and Dermatome in One Precision Instrument

The Stryker Bone Saw is simple, safe and efficient to operate. Oscillating at 28,000 strokes per minute, the saw cannot catch in drapes or sponges, nor throw blood. Equipped with five blades. Adaptable to many varieties of bone surgery. Saw blades can be changed quickly during operation.

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Includes Dermatome complete with blade, thickness gauges and supply of Stryker Skin Tape, plus bone saw, five blades, blade-holder, foam rubber-lined aluminum carrying case. Specify 110 or 220 volts. Either model operates on AC or DC.

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Deep cutting blade, wide
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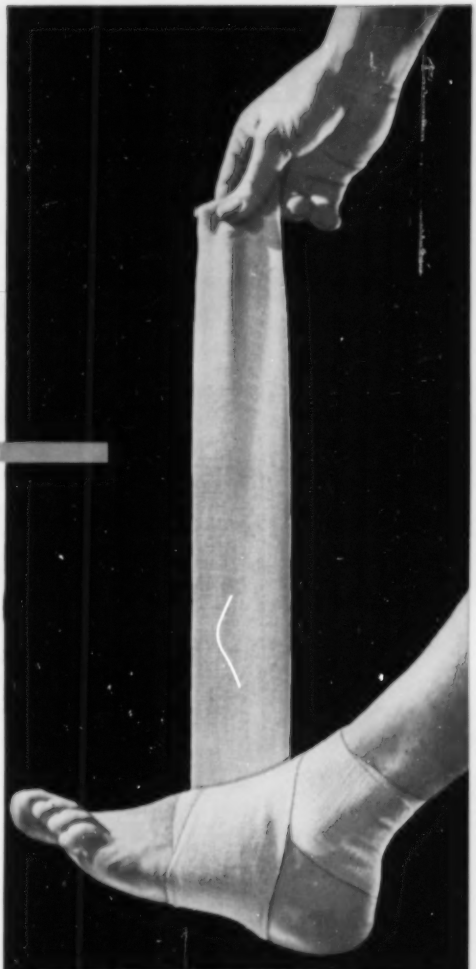
No. 1002-B

Orthopedic

ORTHOPEDIC FRAME COMPANY
Dept. B Kalamazoo, Mich.

The first truly elastic bandage that heat won't hurt



New TENSOR is woven with Heat-Resistant live rubber threads for lasting elasticity

It takes live rubber threads to make a truly elastic bandage. Up to now, however, the live rubber has posed a laundry problem, particularly in high temperature home and commercial dryers.

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Isn't this the kind of elastic bandage you want *your* patients to wear? Why not have your nurse order them next time she replenishes office medical supplies. Available in doctor bulk put-ups at no increase in cost.

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ELASTIC BANDAGE
Woven with Heat-Resistant live rubber threads

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COMPARE THESE ELASTIC BANDAGES

❶ Bandage with ordinary rubber

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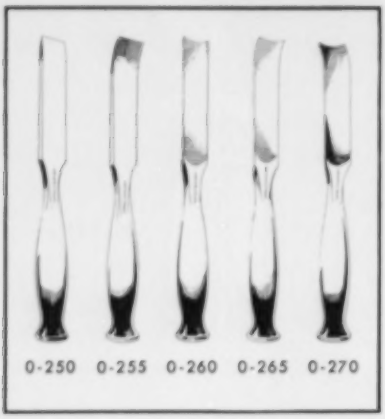
❶ One-foot length of bandage made with ordinary rubber is stretched after high temperature drying—and stays stretched. Its elasticity "died" in the dryer.

❷ But one-foot length of heat-resistant Tensor snaps back to its original length, even after prolonged exposure to near scorching heat of commercial dryer.

SMITH-PETERSEN OSTEOTOMES and GOUGES



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0-250 SMITH-PETERSEN OSTEOTOME—straight, 8", sizes ¼", 3/8", ½", 5/8", ¾", 1" and 1¼". Stainless Steel.

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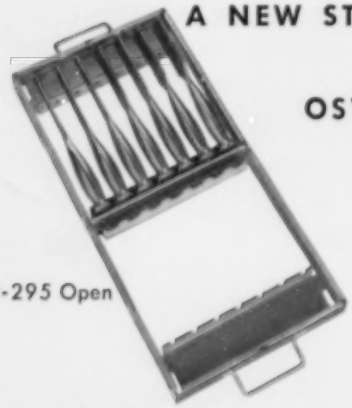
A NEW STAINLESS STEEL CASE TO HOLD SMITH-PETERSEN OSTEOTOMES and GOUGES



0-295 Open

CASE 0-295—holds seven Smith-Petersen Osteotomes.

CASE 0-296—holds seven Smith-Petersen Gouges.

CASE 0-297—holds a combination of seven Osteotomes and Gouges.

Cutting edges are protected at all times.
Complete unit may be autoclaved.

0-295 Closed

Specify Width of Gouges and Osteotomes When Ordering

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The surgical dressing applied by SPRAY

AEROPLAST LIQUID SURGICAL DRESSING offers new efficiency as a protective dressing for routine surgical purposes. Used as the sole dressing agent in an extensive series of laparotomies, thoracotomies, herniorrhaphies, ileostomies, compound fractures, etc., as well as burns, skin graft donor sites, and severe excoriation, Aeroplast has clearly demonstrated important advantages over conventional dressing materials and methods.* Aeroplast dressings are:

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flexible Regardless of where applied, they "fit" and maintain their integrity. They do not restrict desirable motion or circulation.

sterile They are impermeable to bacteria. Properly applied to aseptic lesions, sterility is maintained as long as the dressing is allowed to remain intact. Aeroplast itself is bacteriostatic.

Aeroplast is applied with the press of a button, sprayed directly onto the lesion from a self-contained aerosol "bomb". It is *non-toxic, non-sensitizing, non-allergenic.* Dressings are easily removed, after a period sufficient to allow complete "setting", by simple peeling.

Supplied in 6 oz. aerosol-type dispensers through your prescription pharmacy or surgical dealer.

Send for reprints and literature

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422 Dellrose Avenue, Dayton 3, Ohio

*Choy, D.S.J.: Clinical trials of a new plastic dressing for burns and surgical wounds. A.M.A. Arch. Surg. 68:33-43 (Jan.) 1954

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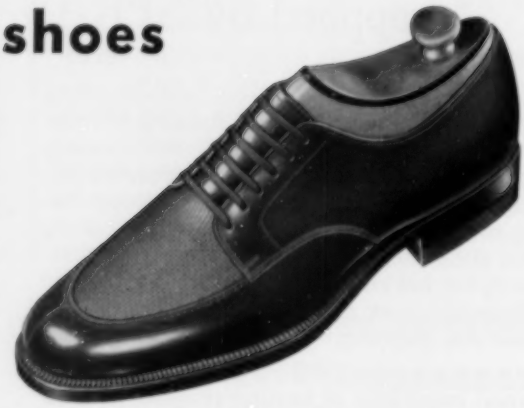
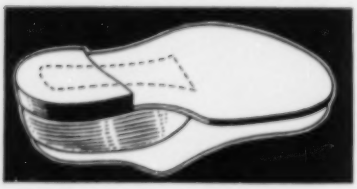
shoes

Alden-Pedic lasts are designed to accommodate your prescribed corrections and insertions. Extreme sizes stocked. Many styles available for men and boys. Top quality only.





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SCIENTIFIC CONSTRUCTION

- Long inside counter
- Heavy gauge ribbed steel shank
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Alden-Pedic lasts and shoes have been scientifically designed and tested to accommodate specific and general degrees of foot disabilities. Doctors who become familiar with the functional merit of this program will be glad to prescribe these shoes as a foundation in the treatment and correction of foot disabilities. We do not claim that these shoes will correct abnormal foot conditions, but they will provide the types of basic footwear necessary as a foundation in aiding foot trouble and in offering foot comfort. We know you will be glad to recommend them.

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a new apparatus for sustained localized heat therapy

HEAT, used alone or in conjunction with chemotherapy and other physical technics, is often the treatment of choice in

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arthritis
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orthopedic problems
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Tropidores offers heat at its best—controlled, sustained, localized, and comfortable—assuring effective therapy and the patient's willing cooperation, with absolute safety.

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Now you can prescribe localized heat therapy with complete confidence—confidence in unvarying temperature for as long as desired, and absolute safety, with Tropidores.

Tropidores provides these outstanding benefits:

1. Continuous flow of warm air, dry or moist, for full treatment period—days or weeks!

2. Constant temperature ±¼°F. variation, electronically controlled* to your prescription.

3. Wide range in temperature available—96°F. to 140°F.

4. Tremendous time and labor savings because the patient is relatively independent, needs minimum nursing attention—the machine does the work, not the attendant.

5. Finger-tip controls for ease and speed in initiating adjusting and maintaining therapy.

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Muscle-Building
Arch Cushions

Ashley TRADE MARK

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Complete catalogue free upon request

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Established 1919
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MADE WITH THE NEW

ARE
- STRONGER
- LIGHTER
- THINNER
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Johnson & Johnson

DEPENDABLE ALWAYS.....

Orthopedic PILOT POINT BONE SCREWS

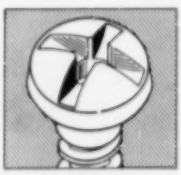
for **QUALITY**

for **REPEAT VOLUME**

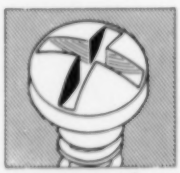
AVAILABLE IN 4 HEAD STYLES

SINGLE SLOT HEAD

CROSS SLOT HEAD



SIMULATED PHILLIPS



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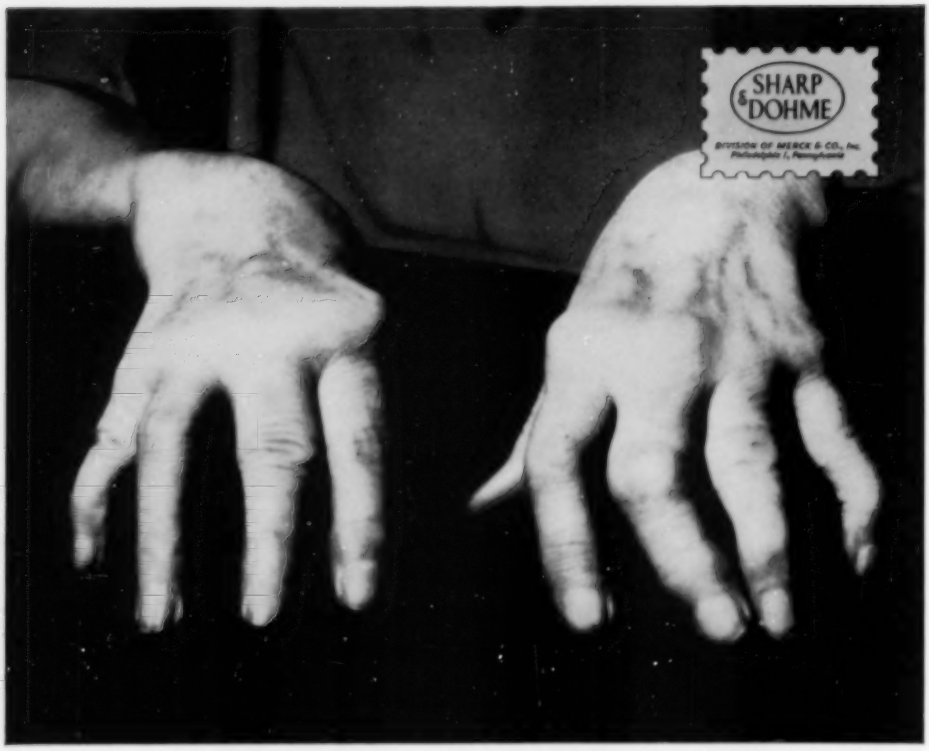

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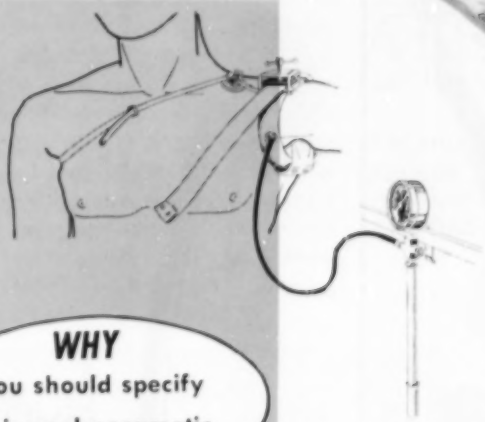

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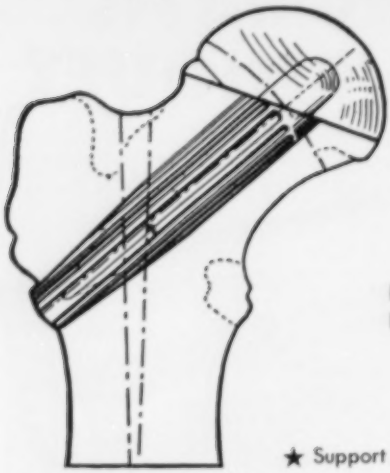

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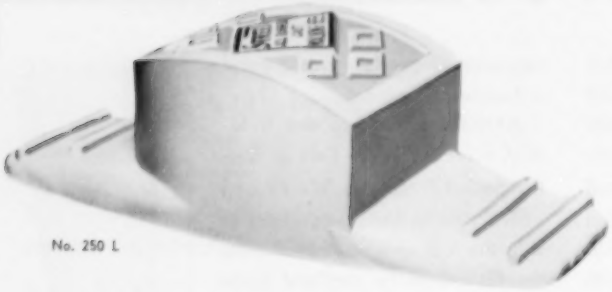

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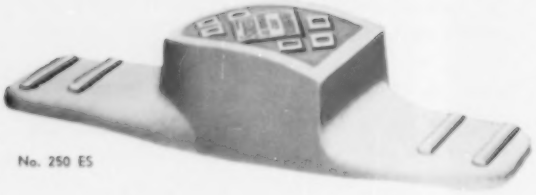

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VOL. 36-A, NO. 3 JUNE 1954

The Journal of
Bone and Joint Surgery

American Volume

FUNCTIONAL RESULTS OF HIP ARTHROPLASTY WITH ACRYLIC PROSTHESIS *

BY R. MERLE D'AUBIGNÉ AND M. POSTEL, PARIS, FRANCE

Six hundred and twenty-one arthroplasties of the hip have been performed since the beginning of 1948 in the *Clinique chirurgicale orthopédique et réparatrice* of the *Hôpital Cochin* and in our private practice (Table I).

TABLE I

HIP ARTHROPLASTIES

Trauma	131
Osteo-arthritis	264
Congenital subluxation	104
Congenital luxation	66
Rheumatoid arthritis	14
Spondylitis ankylosans	26
Miscellaneous	16
Total	621

Careful follow-up has enabled us to determine the functional result in the great majority of our patients (243): of the 340 patients operated upon for osteo-arthritis, trauma, or congenital subluxations of the hip from six months to five years previously, six died (three from postoperative embolisms and three from intercurrent disease later) and eleven were lost to follow-up. All of the other patients have been reviewed at four months, at six months, and at one year after the operation. Thereafter, the patients have been examined once a year.

TECHNIQUE

From 1947 to 1948, the technique advised by Smith-Petersen was used as exactly as possible. In a certain number of patients, however, in whom extensive excision of the femoral head was necessary, we inserted the Judet acrylic prosthesis through the anterior approach.

As the early results in patients in whom acrylic femoral-head prostheses had been inserted were slightly better than the results in those in whom Vitallium cups had been used, we progressively came to prefer, during the year 1948, the use of the acrylic prosthesis. We used Hueter's anterior approach, a conservative excision of the head, and reaming of the acetabulum in order to make it fit the acrylic head exactly. In patients with osteo-arthritis, we always resected the capsule.

The prosthesis used was a slightly modified Judet prosthesis. There was a longer and stronger sleeve at the base of the head. This was exactly fitted around the neck stump which had been shaped by means of a special instrument. It was hoped that this exact fitting would prevent fracture of the stem; this proved after some time to be unfounded,

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, July 1, 1953.

TABLE II

HIP ARTHROPLASTIES WITH ACRYLIC PROSTHESIS: FOLLOW-UP

(Trauma to Hip, Osteo-Arthritis, and Subluxations)

Total no. of patients		405
No. of patients operated upon Jan. 1948 to Nov. 1952	340	
No. of patients operated upon in subsequent six months	65	
Deaths		6
Postoperative	3	
From intercurrent disease in first year	3	
Lost to follow-up		11
Followed-up (not including patients operated upon in last six months)		323
Less than one year	90	
One to two years	116	
Two to three years	79	
Three to four years	34	
Four years or more	4	

for in patients in whom bone absorption occurred at the end of the neck stump the sleeve became loose. Thus, after having observed several fractures of the stem, we began to use a Judet prosthesis with a steel re-enforcement.

At the beginning of 1949, a review of the results in our patients showed 25 to 30 per cent. of the results to be fair or poor. A careful study of these suggested that most of the partial or complete failures were due to the inadequate mechanical conditions of the new joint.

The following points appeared to be particularly important:

1. The conservation or restoration by the prosthesis of the normal length of the femoral neck (Figs. 1-A through 2-C).

2. The correction of anteversion, which was achieved in three ways:

FIG. 1-A

FIG. 1-B

Fig. 1-A: Congenital subluxation with osteo-arthritis.

Fig. 1-B: Fourteen months after arthroplasty. Very bad result. The neck is too short, and anteversion has not been corrected. This patient was subjected to an arthrodesis.

FIG. 2-A

FIG. 2-B

FIG. 2-C

Fig. 2-A: Congenital subluxation with osteo-arthritis.

Fig. 2-B: Arthroplasty with correction of anteversion by the oblique insertion of the prosthesis. The full length of the neck has been restored. Very good result at ten months.

Fig. 2-C: Twenty-one months postoperatively. Slight recurrence of pain. Roentgenogram shows beginning bone resorption around the prosthesis.

FIG. 3

Fig. 3: Correction of anteversion by the oblique insertion of the prosthesis.

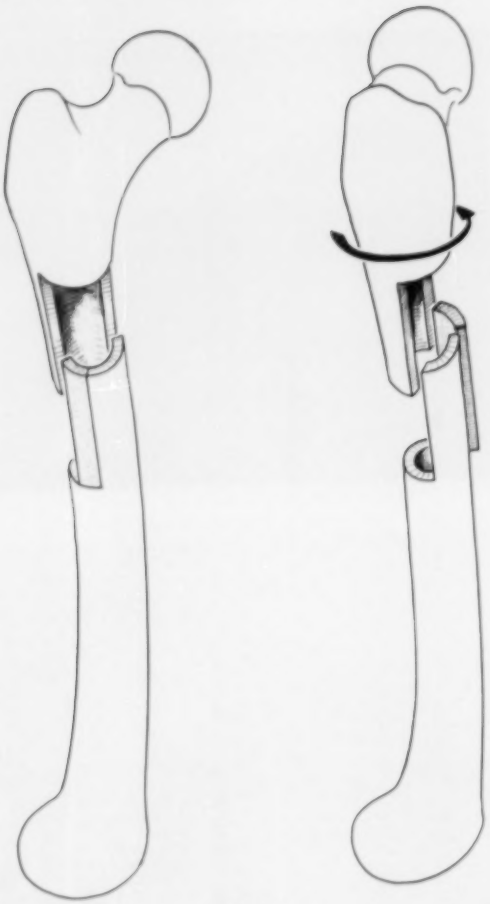

FIG. 4

Fig. 4: Correction of anteversion by osteotomy. An intramedullary nail is inserted. The femur is cut and is rotated around the nail. The crossing of the nail and of the stem of the prosthesis makes this technique difficult. Insertion of a cervico-capital prosthesis is preferable.

A. By the oblique insertion of the prosthesis. A moderate anteversion can be corrected by inserting the prosthesis in a plane more nearly frontal than that of the neck (Fig. 3).

B. By derotation osteotomy of the diaphysis. In six cases, strong anteversion was corrected by a step-shaped osteotomy performed around an intramedullary nail. This was done in the same stage as the arthroplasty. The crossing of the nail and of the prosthetic stem is a delicate step of the operation (Figs. 4, 5-A, and 5-B).

C. By the insertion of the cervico-capital prosthesis. We now prefer to correct strong anteversion by the insertion in the corrected direction of our cervico-capital prosthesis (Figs. 6-A and 6-B).

3. Proper fitting of the acetabulum to the prosthetic head: This was difficult to do in congenital conditions. The necessity of obtaining a good exposure of the posterior and inferior parts of the acetabulum, as well as of the anterior part, appeared evident.

From 1949 to the end of 1952, our technique was modified as follows:

1. Gibson's posterolateral approach was used in all patients in order to obtain a good exposure of all parts of the acetabulum and to enable a thorough evaluation and correction of anteversion.

2. The normal length of the femoral neck was conserved whenever possible. The normal length of the femoral neck was restored by the insertion of the cervico-capital

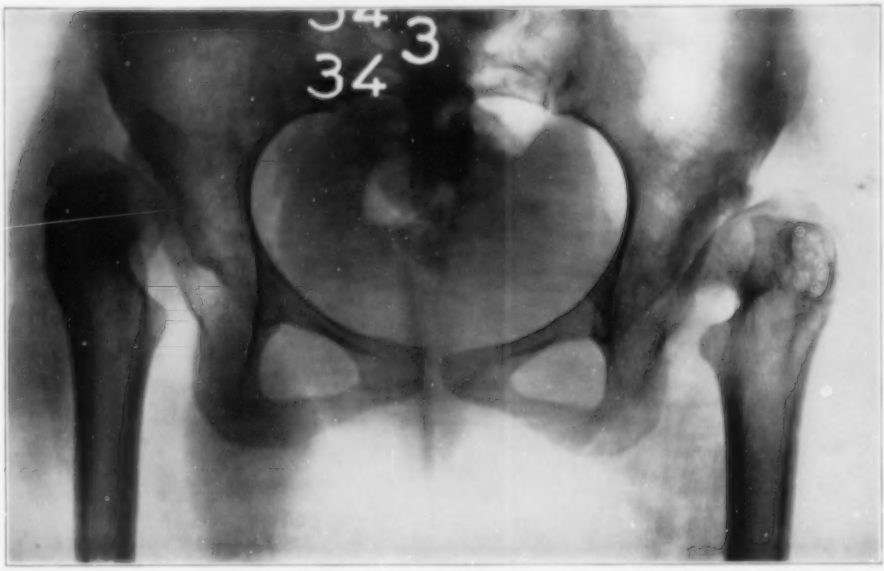

FIG. 5-A

FIG. 5-B

Bilateral congenital dislocation. In the right hip, anteversion of 80 degrees has been corrected by derotation osteotomy during the arthroplasty. Very good result. In the left hip, anteversion has been corrected by the oblique insertion of the prosthesis. Very good result after two years.

prosthesis when the neck had been absorbed or was congenitally short or had had to be resected for a pathological condition.

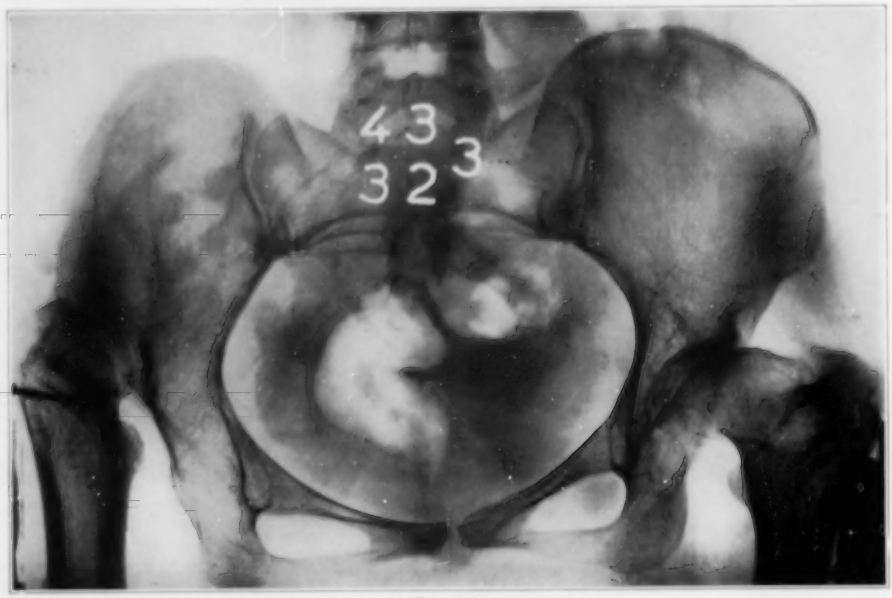

FIG. 6-A

FIG. 6-B

Congenital dislocation of the right hip had been previously operated upon with a poor result. Arthroplasty with the cervico-capital prosthesis and correction of the anteversion brought about a good result. In the left hip residual subluxation was corrected by arthroplasty in which a Judet prosthesis was used. Very good result.

3. The prosthetic head was exactly fitted to the acetabulum.

More recently, at the end of 1952, a review of late results showed that there was late functional deterioration among formerly good or fair results in 15 per cent.

Deterioration appeared to be caused by *bone absorption around the prosthesis.* Believing that absorption is due to a too great pressure of the stem of the Judet prosthesis on the wall of the cervical canal, we have been brought to use our cervico-capital prosthesis with a long intramedullary stem (Fig. 7) even in patients in whom the shortness of the neck did not make it necessary, at least in relatively young patients.

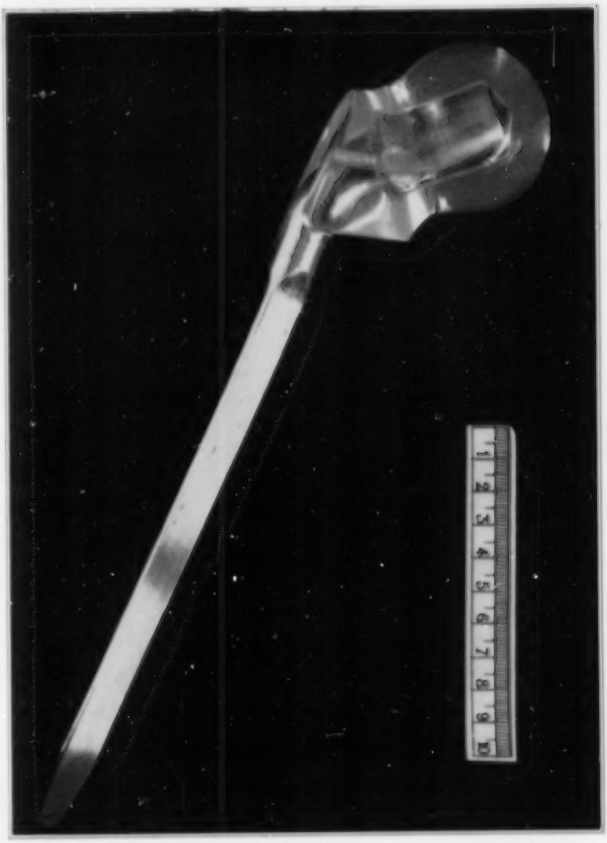

FIG. 7

The cervico-capital prosthesis (modified from that of J. Gosset) with the long intramedullary stem and flat weight-bearing surface.

Present Technique

1. *Approach:* We use in all cases Gibson's excellent posterolateral approach which consists in a slightly posteriorly curved incision, fifteen centimeters long, on the lateral aspect of the trochanter through the skin and fascia lata, together with the section of the glutaeus medius tendon around the trochanter and section of the glutaeus minimus tendon.

2. A T-shaped opening of the capsule is made along its iliac insertion in patients with trauma, while excision of the capsule is done in patients with osteo-arthritis.

3. The hip is dislocated.

4. *Acetabulum:* Nothing is done to the acetabulum when it is sound in patients with trauma to the hip. In patients with osteo-arthritis, conservative excision, with careful removal of bone formations at the inferior and posterior borders, is performed. The acetabulum is carefully reamed to make it spherical and to make it fit the prosthetic head exactly. In patients with congenital subluxations, a new acetabulum has to be created in the posterior and inferior part of the shallow cavity. In patients with high congenital disclocations, the acetabulum is made in the normal place or slightly higher.

5. *Femoral head and neck:* In old patients with a sound and normally anteverted femoral neck, we still use the Judet prosthesis (with steel re-enforcement) which has been modified by being made with a strong, long sleeve and which is exactly fitted by means of a special instrument. In all other patients, we use the cervico-capital prosthesis with an intramedullary stem. In these patients, the femoral neck may have been absorbed (non-

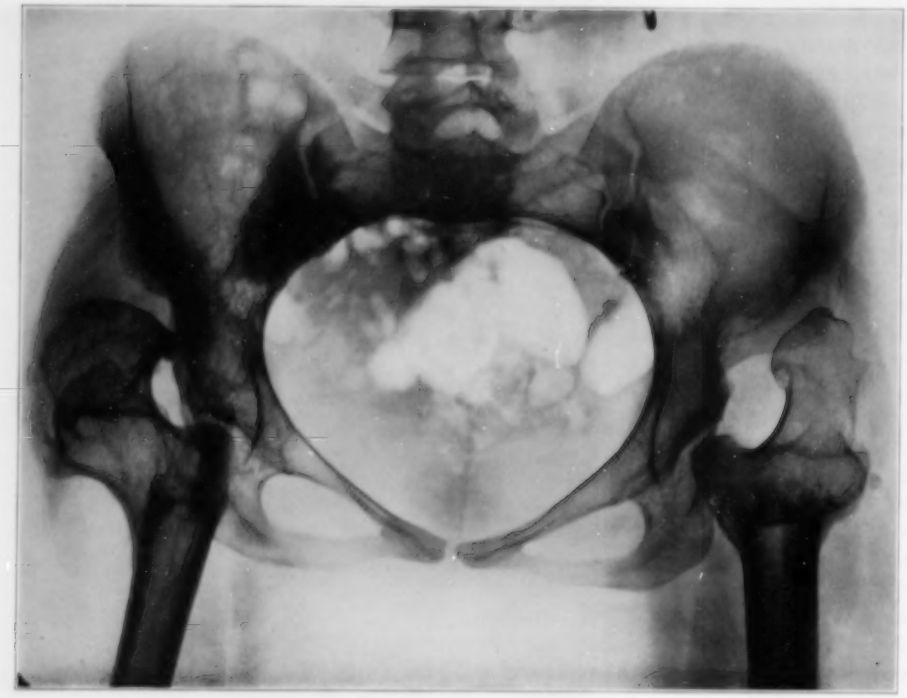

FIG. 8-A

FIG. 8-B

Bilateral congenital dislocation previously treated by osteotomy. There was severe pain and a permanent abduction deformity. Arthroplasty was performed on both sides with the insertion of the cervico-capital prosthesis. Very good result after six months.

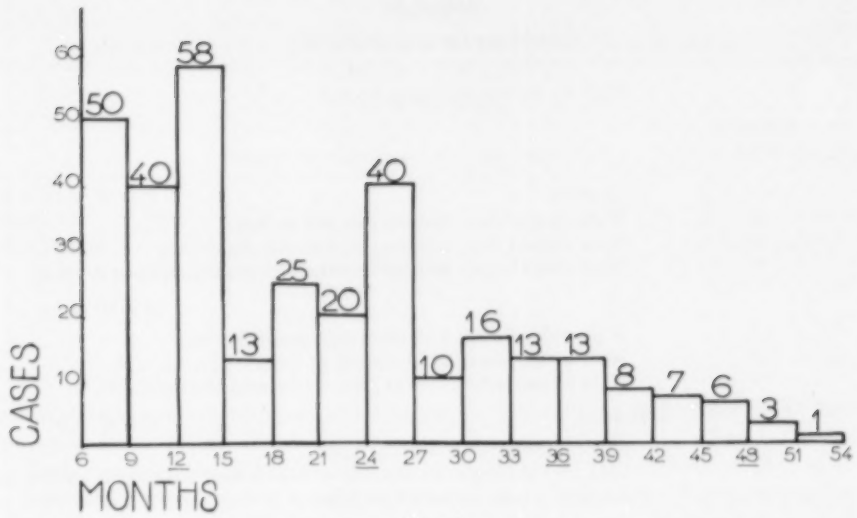

Chart I

Follow-up.

(Reproduced by permission from *Mémoires de l'Académie de Chirurgie*, **79**: 461, 1953.)

union) or the neck may be strongly anteverted, congenitally short, or involved in a pathological condition. The cervico-capital prosthesis is used in all patients under sixty. The neck is resected in two planes: one vertical and sagittal between the trochanter and the base of the neck and the other horizontal just above the lesser trochanter. The medullary canal is opened, and, if necessary, it is widened to permit the insertion of the big steel stem of the prosthesis. The prosthesis is hammered in. The bone sections, however, are made to conform exactly to the prosthesis before it is hammered into place.

6. Finally reduction of the prosthesis into the acetabulum and suture of the tendons and fascia lata with steel wire are done.

TABLE III

METHOD OF GRADING FUNCTIONAL VALUE OF HIP *

	Pain	Mobility	Ability to Walk
0	Pain is intense and permanent.	Ankylosis with bad position of the hip.	None.
1	Pain is severe even at night.	No movement; pain or slight deformity.	Only with crutches.
2	Pain is severe when walking; prevents any activity.	Flexion under 40 degrees.	Only with canes.
3	Pain is tolerable with limited activity.	Flexion between 40 and 60 degrees.	With one cane, less than one hour; very difficult without a cane.
4	Pain is mild when walking; it disappears with rest.	Flexion between 60 and 80 degrees; patient can reach his foot.	A long time with a cane; short time without cane and with limp.
5	Pain is mild and inconstant; normal activity.	Flexion between 80 and 90 degrees; abduction of at least 15 degrees.	Without cane but with slight limp.
6	No pain.	Flexion of more than 90 degrees; abduction to 30 degrees.	Normal.

* Adapted from *Tableau* I, *Revue d'Orthopédie*, **35**: 542, 1949.

TABLE IV

FUNCTIONAL GRADING OF THE HIP

Pain	Ability to Walk		
		Mobility Normal or Nearly Normal	
		Very good	P + W = 11 or 12
6	6	Walk without cane, with no pain and no limp.	
6	5	Walk without cane, with no pain but with slight limp.	
5	6	Walk without cane, with no limp but with slight pain when starting.	
		Good	P + W = 10
5	5	Walk without cane, with slight pain and slight limp.	
4	6	Walk without cane, with pain but no limp.	
6	4	Walk without cane, without pain; a cane used to go outdoors.	
		Medium	P + W = 9
5	4	Slight pain; a cane is used outdoors.	
4	5	Pain after walking some minutes; no cane is used but there is a slight limp.	
6	3	No pain; a cane is used all the time.	
		Fair	P + W = 8
5	3	Slight pain; a cane is used all the time.	
4	4	Pain after walking; a cane is used outdoors.	
		Poor	P + W = 7 or less
		Mobility Reduced	
		If the mobility is reduced to 4, the result is classed one grade lower.	
		If the mobility is reduced to 3 or less, the result is classed two grades lower.	

Prosthesis

Our cervico-capital prosthesis is made of acrylic with the head and neck cut at its inferolateral end by two flat surfaces meeting at right angles. The vertical surface must be adjusted to the medial aspect of the trochanter, and the inferior surface must rest on the base of the neck immediately superior to the lesser trochanter. A strong steel stem, twenty-five centimeters long, which is inserted into the plastic material goes down into the medullary canal. It is cylindrical at its superior third, triangular in its medial part, and flat at its inferior third in order to conform to the posterior curve of the shaft.

We began to use this prosthesis at the beginning of 1951, and we have used it in sixty-five cases. The results to the present have been satisfactory. Three criticisms of its use can be made:

1. As with all acrylic prostheses the wearing-out of the material is to be feared;
2. Its insertion demands the complete excision of the femoral neck;
3. It is necessary to fit the individual patient with the proper sized prosthesis, and in some cases the prosthesis has had to be especially made after accurate measurements on the roentgenograms had been taken.

For these reasons, we are now working on a prosthesis of the same shape but made of stainless steel. This prosthesis will allow its length to be adjusted.

RESULTS

In this paper only the results of arthroplasty with the insertion of an acrylic prosthesis in traumatic and degenerative conditions, as well as subluxations, will be reviewed.

Four hundred and five patients have been subjected to arthroplasty. Six died within

TABLE V

METHOD OF THE EVALUATION OF IMPROVEMENT BROUGHT ABOUT BY OPERATION IN AFFECTIONS OF THE HIP

(Relative Result)

	Preoperative Grading	Postoperative Grading	Difference	Improvement
Pain	3	5	$2 \times 2 = 4$	= 9
Mobility	2	5	$3 = 3$	
Ability to walk	3	4	$1 \times 2 = 2$	
	Very great improvement	= 12 or more		
	Great improvement	= 7 to 11		
	Fair improvement	= 3 to 7		
	Failure	= less than 3		

the first year and eleven were lost to follow-up. The duration of follow-up for 323 patients is shown in Table II and Chart I.

Early results at the end of the first postoperative year are available in 225 cases.

Late results from one and a half years to four and a half years after the operation are available in 153 patients. The shortest period of follow-up for these patients is eighteen months and the longest is fifty-four months, the average being twenty-nine months.

To ensure an objective appreciation of the results, we have used the method of grading shown in Table III.

The results are classified in two ways: *absolute results* (the evaluation of the functional value of the hip after the operation) (Table IV) and *relative results* (the appreciation of the difference between the preoperative and the postoperative functional states, in other words, the functional benefit brought to the patient by the operation) (Table V).

For function of the hip, painlessness and ability to walk are much more important than mobility. For this reason, the first and last numbers are multiplied by two. In this way the grading may be used to compare the results of arthroplasty with those of arthrodesis. For example, a successful arthrodesis in a patient who had a painful congenital dislocation will give:

	Preoperative	*Postoperative*	*Difference*	
Pain	2	6	$4 \times 2 = 8$	= 8 good result
Mobility	5	1	-4	
Ability to walk	3	5	$2 \times 2 = 4$	

In a similar case, partial success of the arthroplasty would give:

	Preoperative	*Postoperative*	*Difference*	
Pain	2	4	$2 \times 2 = 4$	= 7 fair result
Mobility	6	5	-1	
Ability to walk	3	5	$2 \times 2 = 4$	

EARLY RESULTS

Traumatic Cases

Early results of arthroplasty in patients with trauma to the hip best teach us the mechanical conditions which must be fulfilled by the prosthesis in order to provide good balance of the hip.

Since the end of 1948, we have used Judet's acrylic prosthetic head in the treatment of non-union of the femoral neck and of necrosis of the femoral head after fracture or traumatic dislocation. During the first two years, we used an anterior approach (either Smith-Petersen's or Hueter's). In the last two years, we used Gibson's posterolateral approach.

FIG. 9-A

FIG. 9-B

FIG. 9-C

Fig. 9-A: Non-union of the femoral neck with absorption of the neck stump. Fig. 9-B: Arthroplasty was done with a Judet head.

Fig. 9-C: Three years postoperatively, the prosthesis became loose. The head pressed on the lateral part of the roof of the acetabulum. Roentgenogram shows sclerosis and the formation of a cyst. Very bad result.

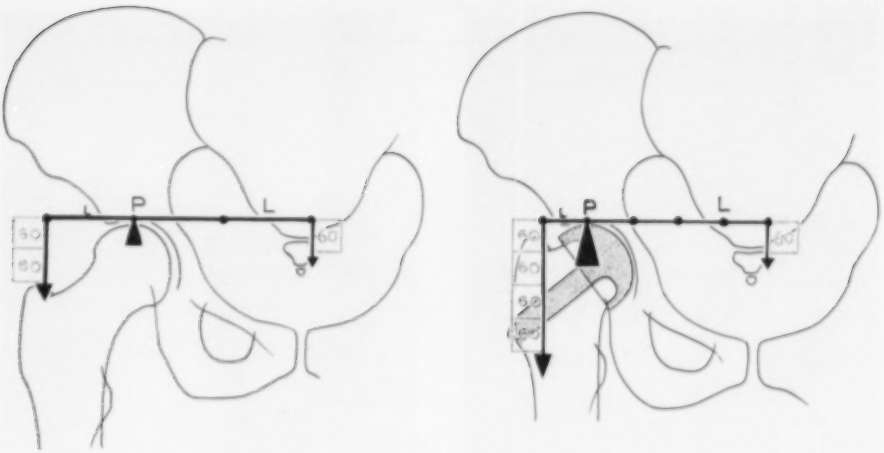

FIG. 10

As shown by Pauwels, pressure on the femoral head is equal to the sum of the weight of the superior part of the body and of the force of the abductor muscles necessary to stabilize the pelvis. If the length of the femoral head is normal, the pressure is three times the weight of the body; if the neck is short, the pressure may be five or six times that weight. (Reproduced by permission from *Revue de Chirurgie*, **71**: 284, 1952.)

Of seventy-six cases, sixty-four have been followed for one year or more. The results are as follows: in 43 per cent. the results were good or very good, in 22 per cent. they were fair, and in 34 per cent. they were poor.

A study of the poor results revealed that these were brought about by the operation, postoperative accidents, or shortness of the stump of the femoral neck.

Accidents were of three types:

1. *Fracture:* Three cases of fracture of the femoral shaft or of the upper extremity occurred during the operation when the anterior approach was used; none occurred during operation when the posterior approach was used.

2. *Fracture of the prosthesis:* Three cases of fracture of the prosthesis occurred with the first type; none have occurred with the use of the new type.

3. *Dislocation:* Ten postoperative dislocations occurred in sixty operations during the first two years. Six of these were reduced by manipulation and four required open operation. The femoral head remained stable in only two, and dislocation recurred in all others. In the majority, the results were poor; some, however, were fair.

Dislocation is evidently due to the shortness of the femoral neck and not to the removal of the capsule, for:

1. We always preserve the capsule in cases of trauma;

2. Since 1951, thanks to preservation or restoration of the normal length of the neck, dislocation has occurred in only two cases of sixty-seven (both of these were satisfactorily reduced by manipulation and the reduction was maintained);

3. Four cases of dislocation have been re-operated upon and a cervico-capital prosthesis has been inserted with very good results.

Shortness of the femoral neck is also responsible for the persistence of pain or for bad balance when no dislocation is present. If the head presses on the lateral part of the roof of the acetabulum and not on the surface, pain is always observed (Figs. 9-A, 9-B, and 9-C).

Even when the head is in the center of the cavity, the shortness of the neck lever may cause pain or bad balance because, according to Pauwels, of the extra weight imposed on the joint (Fig. 10).

Comparison of postoperative results in the patients with normal femoral necks with

FIG. 11-A

FIG. 11-B

Fig. 11–A: Ununited fracture of the neck of the femur previously treated by osteotomy. There was absorption of the neck.

Fig. 11-B: An unsuccessful attempt at arthroplasty with the use of a Judet prosthesis.

FIG. 11-C

FIG. 11-D

Fig. 11-C: One year after the insertion of the cervico-capital prosthesis.

Fig. 11-D: Three years postoperatively. Roentgenogram shows slight absorption of bone under the prosthesis, but there is no looseness. The good result has been maintained.

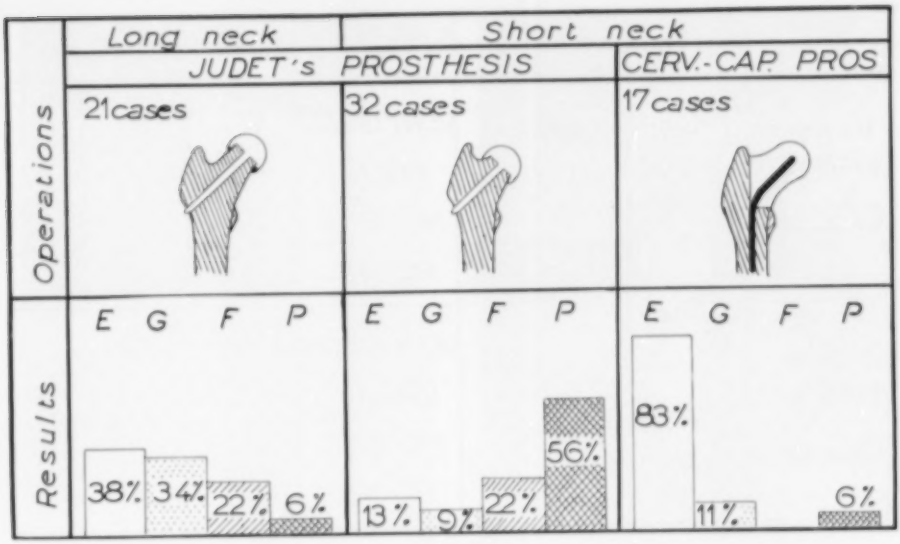

Chart II

Early results from the use of hip prostheses in treatment of non-union of the femoral neck and aseptic necrosis are compared. *E*, excellent; *G*, good; *F*, fair; and *P*, poor.

those in patients with absorbed neck stumps makes quite evident the necessity for the restoration of normal length of the neck.

When the neck is short, 78 per cent. of the results are fair or poor and 22 per cent. are

FIG. 12-A

FIG. 12-B

Fig. 12-A: Ununited fracture of the femoral neck in a patient seventy-five years old. Roentgenogram shows absorption of the neck stump.

Fig. 12-B: Two years after the insertion of the cervico-capital prosthesis. Roentgenogram shows no bone absorption. Good result maintained. Patient uses one cane.

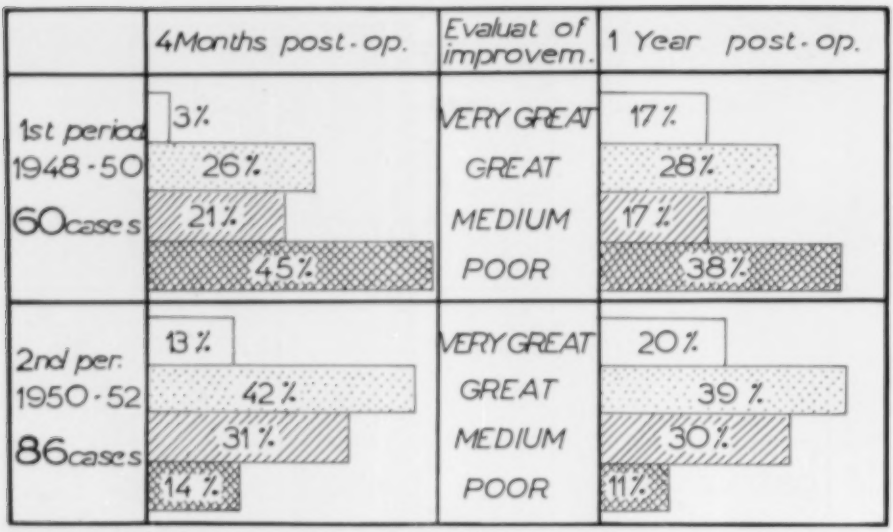

Chart III

Chart shows early results (at four months) and the improvement brought about by the operation (evaluated at one year after the operation). (Adapted from *Tableau* II, *Mémoires de l'Académie de Chirurgie*, **79**: 463, 1953.)

good (Figs. 11-A and 11-B). When the neck is long, 28 per cent. of the results are fair or poor and 72 per cent. are good (Chart II).

Since 1951, we have always used our cervico-capital prosthesis in patients with short neck stumps (Figs. 12-A and 12-B). The results are shown in Chart II.

In patients in whom the neck is nearly normal, about two thirds of the results are good with the use of the Judet head; however, when the neck has been absorbed, the proportion of good results is reversed. In the patients with an absorbed neck stump, the insertion of a cervico-capital prosthesis gave a high proportion of excellent results.

We think our figures undoubtedly show the superiority of the results gained from the use of a prosthesis which restores the normal mechanics of the hip.

	DEATH	INFECTION	DISLOCATION	FRACT. of PROSTHES.
JUDET's head — 1st period 60 CASES	0	5 mild 1 serious	6	5
JUDET's head — 2nd period 86 CASES	2	0	0	4
Cervico-capital prosthesis 13 CASES	1	0	0	0

Chart IV

Chart shows the incidence of early complications and the causes of failure. (Adapted from *Tableau* III, *Mémoires de l'Académie de Chirurgie*, **79**: 464, 1953.)

FIG. 13-A

FIG. 13-B

Fig. 13-A: Ununited fracture of the neck with a long neck stump.

Fig. 13-B: Three and one-half years after the insertion of a Judet prosthesis. Roentgenogram shows no looseness of the prosthesis. Good result was maintained. (The superior part of the femoral-neck stump was broken during the operation; this united.)

Non-Traumatic Cases

The early results of arthroplasty in osteo-arthritis, either essential or secondary to congenital subluxation, show the important influence of technique. In these cases, however, the influence of good technique is limited by the pathological process.

Our experience is discussed for the two periods:

From 1947 to 1950, we used the Smith-Petersen technique which consisted in a wide anterior approach, the interposition of a Vitallium cup, and the creation of a wide acetabulum which allowed mobility both in the acetabulum and at the neck stump. At the beginning of our experience with the use of the Judet acrylic head, we were under the influence of these principles and our attention was focused on mobility rather than on the stability of the hip joint.

From 1950 to the present time, our approach to the problem has been slightly different. Our aim is to obtain a mechanically stable joint, the parts of which are fitted to each other with precision, and to accept the risk of a limitation of mobility.

In this last period our technique is characterized by points which have already been emphasized:

1. Good exposure of the entire joint anteriorly and posteriorly by means of Gibson's posterolateral approach;

2. Preservation or reconstruction of the normal length of the femoral neck;

3. Correction of anteversion in patients with congenital conditions;

4. The exact fitting of the prosthetic head to the acetabulum (such an exact fitting allows only two or three millimeters of joint space).

The comparison of the early functional results from the use of the two techniques may teach us whether or not the later modifications in technique are improvements (Chart III).

During the period 1947 to 1950, 45 per cent. of the patients showed really good results after one year, but 17 per cent. showed fair results and 38 per cent. showed unsatisfactory results. During the period 1950 to the present, good results were seen in 55 per cent. of the patients after four months, and good results were seen in 59 per cent. after one year. Only 11 per cent. showed unsatisfactory results (Chart III).

It may be concluded from these figures that, with the creation of a mechanically well adjusted hip, good function is more quickly and more frequently obtained.

If we consider the postoperative accidents and complications (Chart IV), we find that there were fewer accidents with the use of the later technique, with the exception of fractures of the prosthesis which should be completely overcome in the future through the use of our new device.

Postoperative dislocations have not occurred because of the preservation or restoration of the normal length of the femoral neck.

Study of early results of arthroplasty enables us to say that, during the first postoperative year, the functional result depends mainly upon the mechanical conditions. If the trouble is essentially mechanical, as in cases of trauma and in a certain number of cases of congenital or acquired deformity, good technique gives a high percentage of excellent functional results.

The prospects are less favorable in the presence of progressive degenerative conditions.

All of this leads one to ask the question: How do the good results stand the test of time?

LATE RESULTS

Follow-up of patients after one year may show three things:

1. *Improvement by adaptation* of the muscles and the joint to the new conditions created by the operation.

FIG. 14-A

FIG. 14-B

Fig. 14-A: Arthroplasty with interposition of the Judet prosthesis for osteo-arthritis of the hip.

Fig. 14-B: Three years and ten months postoperatively. Roentgenogram shows very great bone absorption around the prosthesis, loosening of the prosthesis, and absorption of the acetabulum. Functional result, which was good, has deteriorated after one year.

Duration of follow-up		RESULT 1yr POST-OP.	EVOLUTION IN BETWEEN	RESULT at LAST EXAM.
1 ¼ to 2 yrs 61 cases	GOOD	31	13	34
	MED.	15		10
	POOR	15	13	17
2 to 3 yrs 58 cases	GOOD	29	17	32
	MED.	15		13
	POOR	14	15 (26%)	13
more than 3 yrs 34 cases	GOOD	16	7	17
	MED.	8		8
	POOR	10	8 (25%)	9

Chart V
Evolution of functional result.

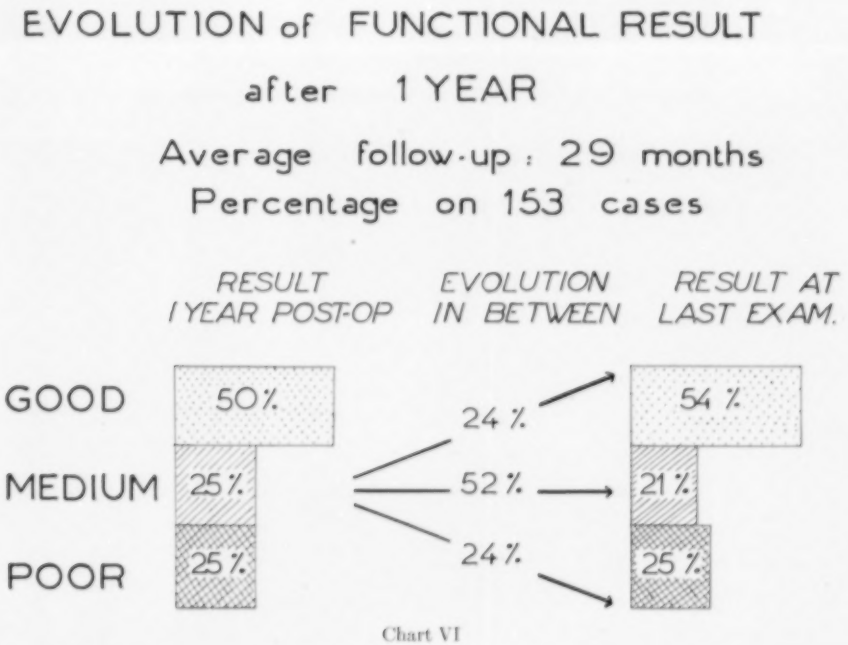

Chart VI

2. *Stability:* A patient, now aged seventy, whose hips are shown in Figures 13-A and 13-B, who had been subjected to one of our first arthroplasties showed a consistently maintained result fifty-four months after operation.

3. *Deterioration:* The function of the hip after the operation may grow worse because of (a) deterioration of the prosthesis itself by fracture or by wearing, (b) resorption of

the bone caused by the mechanical action of the foreign body, and (c) the persistence of the degenerative process which, of course, had not been suppressed by the operation.

From this point of view, we have reviewed all of the patients with trauma, osteo-arthritis, or congenital subluxations followed for more than eighteen months, and we

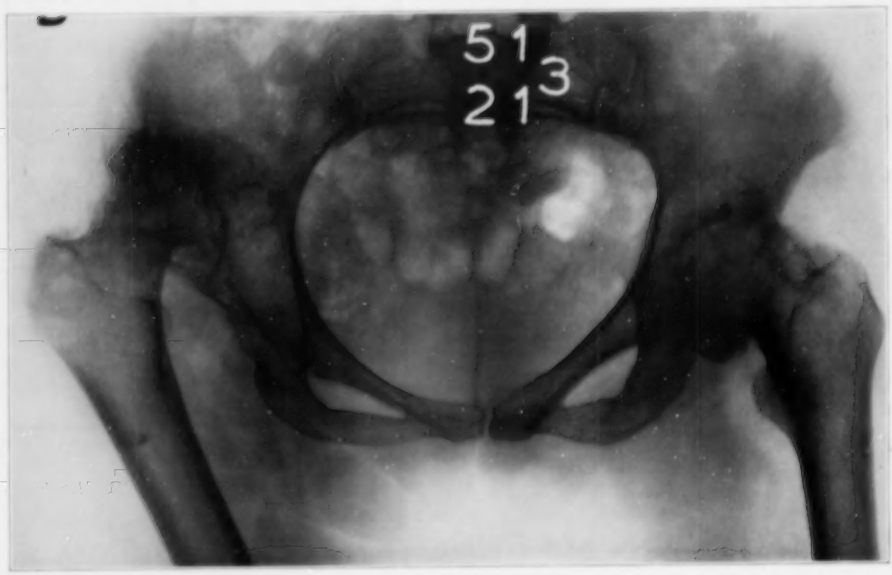

FIG. 15-A

Osteo-arthritis of the left hip. Congenital dislocation of the right hip.

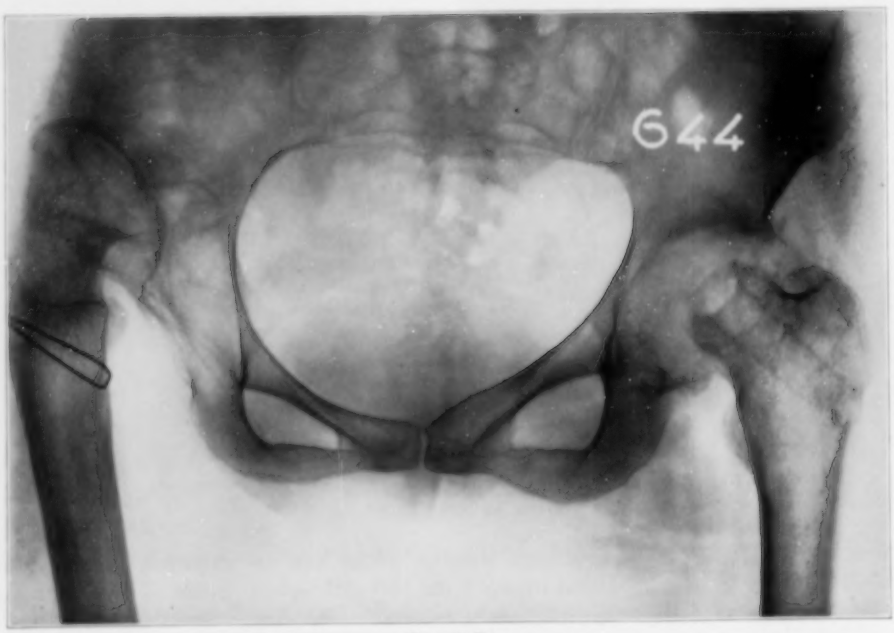

FIG. 15-B

Osteotomy of the right hip. Arthroplasty of the left hip. Good result one year postoperatively.

TABLE VI

LATE DETERIORATION OF RESULTS

(After one Year)

				No. of Cases
Frequency				
Osteo-arthritis and subluxations				21 of 100
Trauma				8 of 53
				Total 29 of 153
Symptoms				
Impaired Mobility (*No. of Cases*) 3	Increased Pain (*No. of Cases*) 8	Increased Pain and Impaired Ability to Walk (*No. of Cases*) 14		Increased Pain and Impaired Ability to Walk and Impaired Mobility (*No. of Cases*) 4
Degree of Deterioration				
Slight (*No. of Cases*) 8		Medium (*No. of Cases*) 18		Serious (*No. of Cases*) 3
Postoperative Functional State Compared with That before Operation				
Much Better (*No. of Cases*) 7	Better (*No. of Cases*) 12		Same (*No. of Cases*) 5	Worse (*No. of Cases*) 5

FIG. 15-C

Two and a half years postoperatively, roentgenogram showed bone absorption in the neck and acetabulum. Functional result deteriorated.

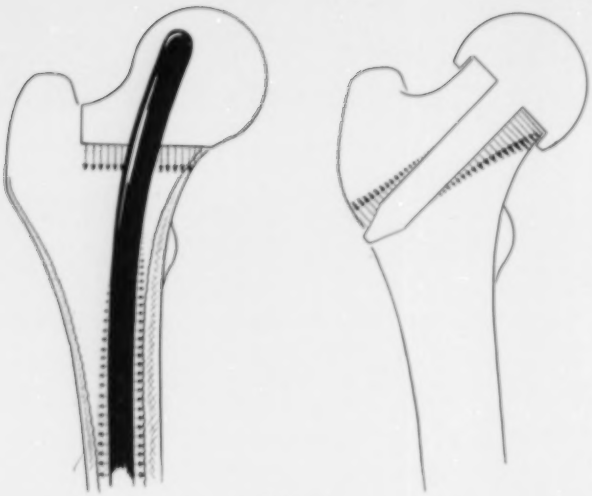

FIG. 16

Diagram shows the influence of pressure on bone absorption. With the use of the Judet prosthesis (right), absorption widens the cervical canal; the prosthesis becomes loose and absorption is aggravated. When the cervico-capital prosthesis is used (left), the device presses on a more vascularized part of the femur. Even with slight absorption, the prosthesis will not tilt nor will it become loose.

have compared the functional state at the end of the first postoperative year with that at the last examination. This comparison was possible in 146 of our patients.

This comparison was done separately on cases of trauma, on cases of osteo-arthritis, and on cases of congenital subluxation; but, as we found that the postoperative course was practically the same in the three groups, all of the cases have been grouped in one chart (Chart V). In this chart, the patients have been divided into three groups, according to the duration of the follow-up: one and one-half to two years, two to three years, and three years or more.

The left-hand column shows the number of good, medium (fair), and poor results one year after the operation. The central column gives the number of patients in whom the result has improved or has worsened between the examination at the end of the

FIG. 17-A

FIG. 17-B

Fig. 17-A: Roentgenogram shows necrosis of the femoral head after traumatic dislocation in a girl, twenty-one years old.

Fig. 17-B: Two years after the operation. The functional result was excellent for one and a half years. The patient, at the time this roentgenogram was made, was pregnant; some pain had recurred. Roentgenogram shows slight absorption of the neck around the prosthesis.

first postoperative year and the last examination. In the right-hand column are shown the proportion of good, medium (fair), and poor results seen when the patients were last examined.

It must be pointed out that the percentage of deterioration is about the same (20 to 25 per cent.) in the cases reviewed after two years, three years, or four years. This may suggest that deterioration generally occurs during the second year and that the number will not rise very much with the passing of time (Chart VI).

In Chart VI, all of the cases are grouped without consideration of the duration of the follow-up. It is clearly shown that the proportion of more or less improved results is approximately the same at the last examination as that at the end of the first year. This is due to the fact that the impaired results are balanced by an equal number of improved results. The late improvements are due to the wonderful adaptability of nature. These must not, however, cause us to forget deterioration for which, even if we do not hold ourselves responsible, the patient may.

The fact is that 20 per cent. of our results do not last. One of five patients, happy one year after operation, will have a partial (sometimes total) recurrence of his condition (Table VI).

The degree of impairment of the result varies. When we compared the functional state of the patient at the last examination with that before the operation, we found that five patients were as badly off as they had been before the operation and that five were worse. However, seven of these had shown poor results from the beginning.

The causes of late deterioration are not always easy to find. Information may be obtained by clinical examination, roentgenograms, and operative findings (Table VII).

In nineteen of twenty-nine cases, impairment of the result was possibly due to fracture of the prosthesis, wearing of the prosthesis, or bone absorption around the prosthesis.

We believe that these complications can probably be eliminated by a better designed prosthesis:

1. *Fracture of the acrylic prosthesis* may be avoided by the central steel stem of the Judet device; most of those which broke had not been equipped with this stem. However, we have seen three fractured stems *with* the steel re-enforcement.

2. *Wearing of the prosthesis* was found in more than half of the acrylic prosthetic heads removed one year or more after the operation. This is reason enough to prefer a steel or Vitallium prosthesis to one made of acrylic.

3. *Bone absorption is* a more serious matter. It occurs chiefly on the neck stump, with sclerosis, sharpening of the end of the stump, and widening of the canal (Figs. 14-A and 14-B). The acetabulum may also show absorption, although in fewer cases (Figs. 15-A, 15-B, and 15-C). Bone absorption is sometimes seen in the roentgenograms of patients in whom a good result has been maintained (Table VIII).

In our experience, bone absorption was found in eight patients of 124 in whom results were maintained, while it was present in nineteen patients of twenty-three with impaired results. This fundamental difference in incidence suggests that bone absorption and the consequent loosening of the prosthesis are the chief causes of late recurrence of pain.

The cause of bone absorption is probably the very strong pressure put on a small surface of bone, perhaps less resistant on account of poor vascularization. If this is true, absorption must be greater laterally on the upper border of the canal and medially on the inferior border; the prosthesis will tilt and tend to come to a horizontal position (Figs. 16 through 18-B). This is quite obvious in the roentgenograms of some patients.

Progressive mobility of the prosthesis makes absorption more and more inevitable.

Bone absorption in the acetabulum is difficult to prevent, but loosening of the prosthesis in the femur can be sharply reduced, and perhaps even suppressed, by a

TABLE VII

LATE DETERIORATIONS

(Roentgenographic and Operative Findings)

	No. of Cases
Periarticular bone production	4
Joint stiffness without bone formation	2
Bone absorption around prosthesis:	
with fracture of prosthesis	5
with prosthesis unchanged	6
with wearing	8
No particular findings	4
Total	29

TABLE VIII

BONE ABSORPTION AROUND THE PROSTHESIS

Functional Status	Appearance Normal as Seen by X-Ray (*No. of Cases*)	Bone Absorption (*No. of Cases*)
Maintained	116	8
Deteriorated	23	19

better design of the prosthesis which should meet two specifications:

1. Distribution of pressure on as large a surface of bone as possible;

FIG. 18-A

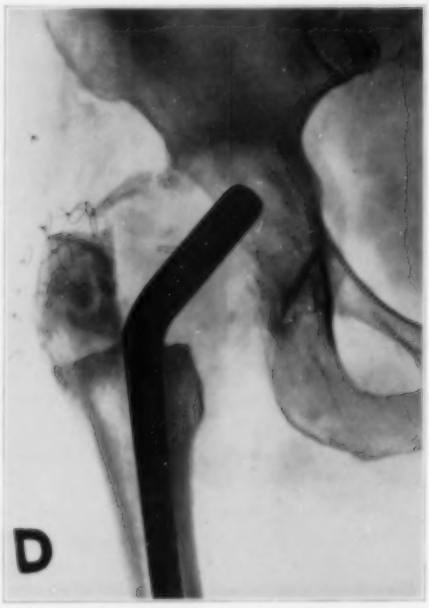

FIG. 18-B

Fig. 18-A: Osteo-arthritis of the hip. Patient was operated upon in another hospital; two years after the operation there was great absorption and tilting of the prosthesis. A very bad result.

Fig. 18-B: Six months after the insertion of the cervico-capital prosthesis, there was a good functional result.

2. A design which, if some absorption occurs, will not allow progressive mobility of the prosthesis.

Our *C* prosthesis with the long intramedullary nail and flat weight-bearing surface seems to be the answer to these conditions. If absorption occurs on the weight-bearing surface, the piece will go slightly further down into the femur, but it will not tilt.

So far, in seventeen patients followed for more than two years, we have seen neither any clinical impairment nor roentgenographic evidence of loosening.

CONCLUSION

Results in hip arthroplasty with an inert prosthesis are very encouraging in the treatment of non-union of the femoral neck, traumatic necrosis of the femoral head, and osteo-arthritis. Unfortunately, a certain number of patients are not improved (20 per cent.) or, after one or two years' improvement, suffer a partial or total recurrence of pain. Some of these failures are due to the persistence or the recurrence of the degenerative condition and cannot be avoided by technical improvements.

However, a fair number of failures are caused by mechanical disorders. Wearing or fracture of the prosthesis can certainly be eliminated by the use of a prosthesis made of inert metal rather than of acrylic. The ill effects of the absorption of bone in the upper end of the femur can probably be avoided by the better design of a prosthesis which will distribute pressure over a wide surface and prevent loosening of the prosthesis.

SUMMARY

Late results in 243 arthroplasties with an acrylic prosthesis for traumatic or osteo-arthritic conditions are reported.

Early results (after one year) show the importance of the restoration of the normal mechanics of the hip joint by the preservation or the restoration of normal length of the femoral neck, the exact correction of anteversion, and the precise fit of the prosthetic head to the acetabulum. A good exposure of the joint through the posterolateral approach appears necessary in order to fulfill these conditions.

Late results (from two to five years) show deterioration of the functional results in 20 per cent. These deteriorations appear to be caused by bone absorption around the Judet prosthesis and the consequent loosening of the prosthesis.

A new type of cervico-capital prosthesis is proposed which makes possible:

1. Restoration of the normal length of the femoral neck when it is congenitally or pathologically short;

2. Correction of anteversion, even when very marked;

3. A weight-bearing surface on a more vascularised part of the femur;

4. The distribution of pressure on bone so as to lessen bone absorption, to prevent its ill effects, and, particularly, to decrease mobility of the prosthesis.

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MY PRESENT ATTITUDE TO OSTEO-ARTHRITIS OF THE HIP *

BY PROF. BRYAN McFARLAND, LIVERPOOL, ENGLAND

It gives me great joy to be here, and I am very conscious of the high honor you do to me and to my country.

I do not know the best treatment for osteo-arthritis of the hip. In fact I do not know that there *is* a best treatment. My present theme is that when an operation becomes necessary, we must pick the procedure most appropriate to a particular patient. Easy, attractive, and immediately satisfying though the new technique of arthroplasty may be, it is neither justifiable nor possible to discard other well-tried operative methods. There are indeed patients for whom each of these methods may be the most suitable. New types of inert material have brought arthroplasty strongly back into favor and may in fact lead the way to something more permanently acceptable. However, the procedure is unlikely to endure unless we learn more about the origin of the pain and unless we use materials which are more natural to, and conform more closely with, the tissues of the human body.

The elaboration and illustration of this theme will fully occupy the space at my disposal. Consequently important and interesting though it is, treatment in the early phases cannot now receive more than a passing glance. I will only say that, in the stage when there is quite good movement, when the roentgenographic changes are minimal and the general function of the hip is fairly useful, when obviously operative intervention is not justified, and yet the patient is inconvenienced by diminishing movements and by discomfort and even pain, I have found that by reducing overweight, by simplifying the diet, by regular reasonable purgation, and by exercises determinedly directed toward increasing internal rotation and abduction movements, pain may in fact be so reduced and activity so increased that operation is sometimes indefinitely postponed.

FIG. 1-A

J. W., an eighteen-year-old boy with a traumatic dislocation.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, July 1, 1953.

I propose to spend no time on measures like manipulation, cheilotomy, neurectomy, and capsulectomy, which in the past have been thought attractive. The improvement they produce is short-lived, and deterioration is often accelerated. Their attractiveness is meretricious and they are best avoided.

Conservative or nearly conservative treatment clearly has a part to play, but in a discussion of osteo-arthritis, the words of Robert Burns come to mind:

"Nae man can tether time or tide,
The hour approaches Tam maun ride."

He might well have been speaking of the arthritic hip, which usually by inexorable progress reaches the stage when, either because of pain so acute as to cause sleeplessness, or because of pain which, although only moderately severe, is aggravated by accompanying deformity, something radical must be done. Sooner or later the patient becomes seriously disabled, and we must consider what we can do. We can fuse the hip by arthrodesis, we can change the line of weight-bearing by osteotomy, or we can fashion a new joint by arthroplasty. I believe that in its turn each of these three measures has its place, and that we best serve our patient by using the one most appropriate to all the features of his case. We must suit our operation to the patient with the same care we exercise in selecting an instrument precisely fitted to a particular job.

Of course the groups overlap, but roughly patients with severely osteo-arthritic hips fall into three groups: those for whom, all things being equal, arthrodesis is most appropriate; those for whom osteotomy is suitable; and

FIG. 1-B

A roentgenogram made two years later showed aseptic necrosis and arthritis.

FIG. 1-C

Roentgenogram made after an arthrodesis had been performed. The patient is now working as a laborer.

FIG. 2

FIG. 3

FIG. 4

Fig. 2: Roentgenogram showing late stage of slipped upper femoral epiphysis; arthritis is evident.

Fig. 3: Late unilateral congenital subluxation, with increasing arthritis.

Fig. 4: Roentgenogram showing arthritis secondary to Perthes' disease.

those for whom arthroplasty is "the only way".

Arthrodesis is appropriate to patients who are young, and whose arthritis is secondary to an obvious cause and involves only one hip, while the other hip is not threatened or ever likely to be. A good example is a young man whose arthritis arose from aseptic necrosis consequent to a traumatic dislocation (Figs. 1-A, 1-B, and 1-C).

In this group, also, one may place those patients whose arthritic changes result from a slipped epiphysis (Fig. 2), unilateral congenital subluxation (Fig. 3), Perthes' disease (Fig. 4), fracture-dislocation (Figs. 5-A and 5-B), and coxa magna (Fig. 6),—in other words, young patients with monarticular secondary arthritis.

The second group is comprised of patients for whom change of weight line by osteotomy is indicated. They tend, of course, to be older, usually middle-aged, and have only one hip affected. Perhaps quite a useful range of movement has been retained, but the patients suffer markedly from pain.

Some care should be exercised in selecting patients for osteotomy, which should, of course, never be done for patients with long femoral necks or with abduction deformity. It is particularly suitable for a patient whose femoral neck is grossly shortened and in whom there is marked adduction deformity. Figure 7 shows an example of a case in which arthroplasty would be inappropriate and osteotomy is the most appropriate procedure.

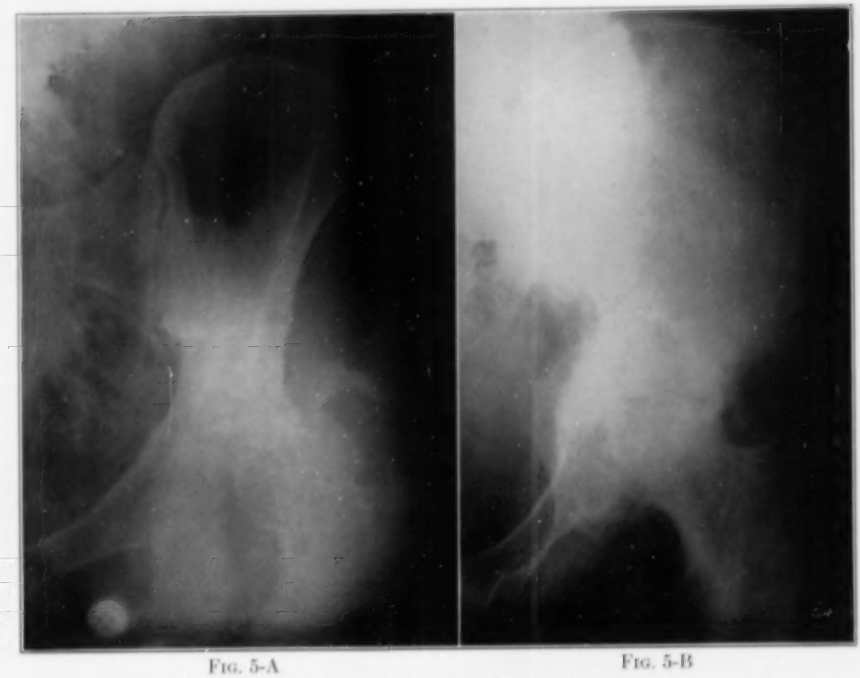

FIG. 5-A

Showing a traumatic fracture-dislocation.

FIG. 5-B

Arthritis following the fracture-dislocation.

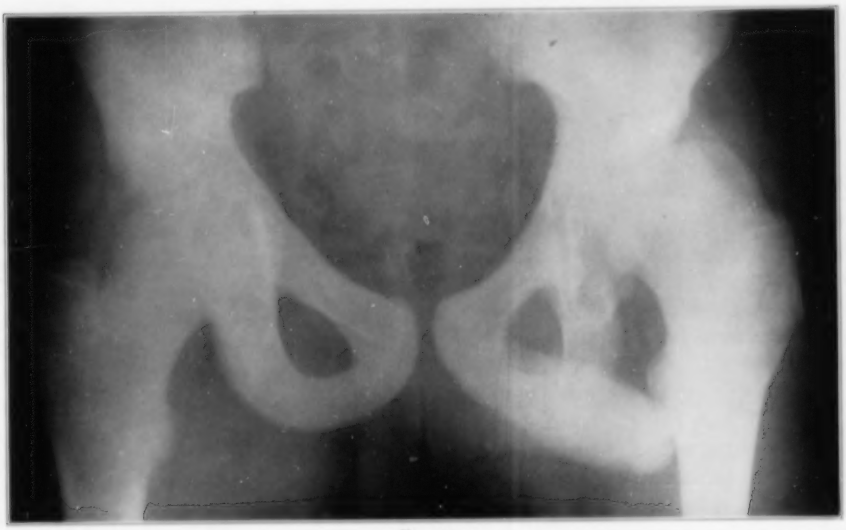

FIG. 6

Coxa magna resulting from a low-grade infection of the neck of the femur in childhood.

It may be well to mention a few points about the technique of the displacement osteotomy. First of all the level ought to be carefully selected: The medial end of the line of osteotomy ought to be just above the lesser trochanter; the lateral end should be at a slightly lower level, so that the line itself is a little oblique; the lateral end is usually at the base of the subtrochanteric fossa. The displacement must be about half the diameter of

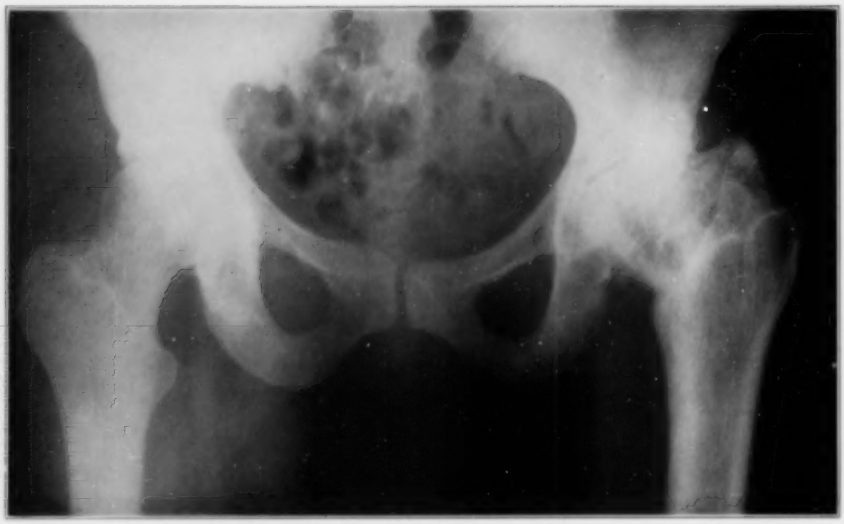

FIG. 7

Because of gross osteo-arthritis and a short femoral neck, this case was unsuitable for arthroplasty but eminently suitable for osteotomy.

the femur, neither more nor less. Great care must be taken to divide the calcar femorale; if the femur splits vertically with the calcar still attached to the lower fragment, displacement is impossible (Figs. 8-A, 8-B, and 8-C).

Figure 9 shows a typical displacement osteotomy. Questions have often been asked as to how good are the results of osteotomy (the intention being to imply that they are bad) and how long good results, if any, are maintained (with the inference that they are short-lived).

I was interested to assess patients other than my own, and so I wrote at random to about twenty "old patients" of McMurray (two years, in fact, after his death) and a dozen or so came to be examined and cinematographed. From their statements at that time I prepared précis of their preoperative and postoperative condition, and the repetition of improvement and satisfaction is almost monotonous. To interview at one sitting a series of "old osteotomy" patients is startlingly impressive. They do not (as the cinematograph demonstrates) walk perfectly, but they are very active; they get about without pain; they work and play; and they do not complain. In their opinion even the tedium of the long recumbent immobility was justified by the result. These photographs and statements were taken from a totally unselected group of patients six, seven, eight, or ten years after an operation which had been done by somebody else, and I had no personal interest in how good or how bad the results might be.

I was working with McMurray during the introduction and the development of the osteotomy in its application to osteo-arthritis of the hip, and I have employed the operation something over two hundred times during the succeeding twenty years. I do not remember a really dissatisfied patient.

The rationale of the operation is obscure and its beneficial effect is difficult to explain. Sometimes pain is relieved, although displacement does not persist. An example is provided by Mrs. D., now eighty-two years old. Before her operation at the age of seventy-seven, she could hardly walk; her neighbors did her shopping; she never went out except to go to church and then in a taxi provided for her by the parishioners. It was agony to see her get in and out of the car, and in church she had a seat near the door. She was very frail and some old nasopharyngeal and respiratory infective condition forced me to perform

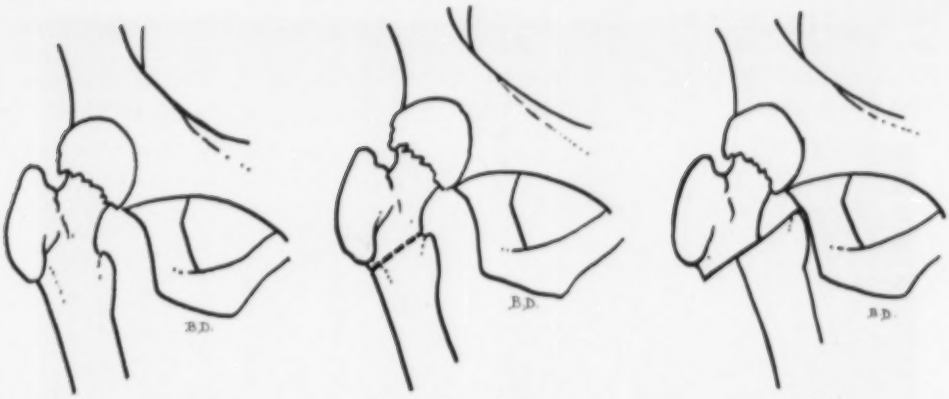

FIG. 8-A FIG. 8-B FIG. 8-C

Diagrams showing the osteotomy line and the amount of displacement.

the osteotomy in a few minutes; postoperative fixation was interrupted by an aggravation of the old infection and the displacement was not maintained (Figs. 10-A and 10-B). Six months after the operation she was doing all her own housework and all her own shopping; she paid social visits and still does so. It is now five years since the operation, but she repeatedly travels from Warrington to Liverpool, about twenty miles, just "for a day out". When photographed again a few weeks ago, she had just finished her spring cleaning (Fig. 10-C . This description may possibly convey the impression, shown on the film so vividly and so clearly, of the ease with which she moves briskly about. She was relieved of her symptoms to an extent which would have been surprising after any procedure. Yet, as I have said, displacement was not maintained; in fact the femur reverted to its original line and shape. Since her hip moves reasonably well, her relief was not due to ankylosis. Why then was she relieved?

FIG. 9

Roentgenogram showing a typical osteotomy.

We come now to our third group—those patients for whom arthroplasty is a *sine qua non*. Their second hip is either already severely affected or is in immediate jeopardy or is certain to degenerate. For these no treatment other than arthroplasty is worth considering. Also it must be admitted that this third group grows in number at the expense of the second, because arthroplasty offers with reasonable certainty relief of pain with useful movement, and most particularly a short, free after-treatment.

I leave out, and it is not an oversight, the metallic cup—or mold—arthroplasty, with which the name of Smith-Petersen is so honorably associated. I leave it out because I do not use it any longer. I admit that, being by temperament opposed to metallic foreign bodies inserted into the human frame, I have never been wildly enthusiastic. But my positive dislike has arisen from the uncertainty of the result. By this I mean that, if I have two apparently exactly similar hips and in relatively similar patients, on each of whom I perform an apparently identical operation without untoward postoperative incident, one result may be very good and the other very poor. Moreover, I do not know why the

one is very poor and I do not know that it is going to be very poor. So that, when at the preoperative consultation the patients ask me what the outcome will be, how long they will be incapacitated, how much movement they will have, *et cetera*, I cannot answer with confidence.

FIG. 10-A

FIG. 10-B

Fig. 10-A: Mrs. D., seventy-seven years old. The roentgenogram showed gross arthritis.
Fig. 10-B: In spite of the postoperative failure in displacement, the patient had been completely relieved.

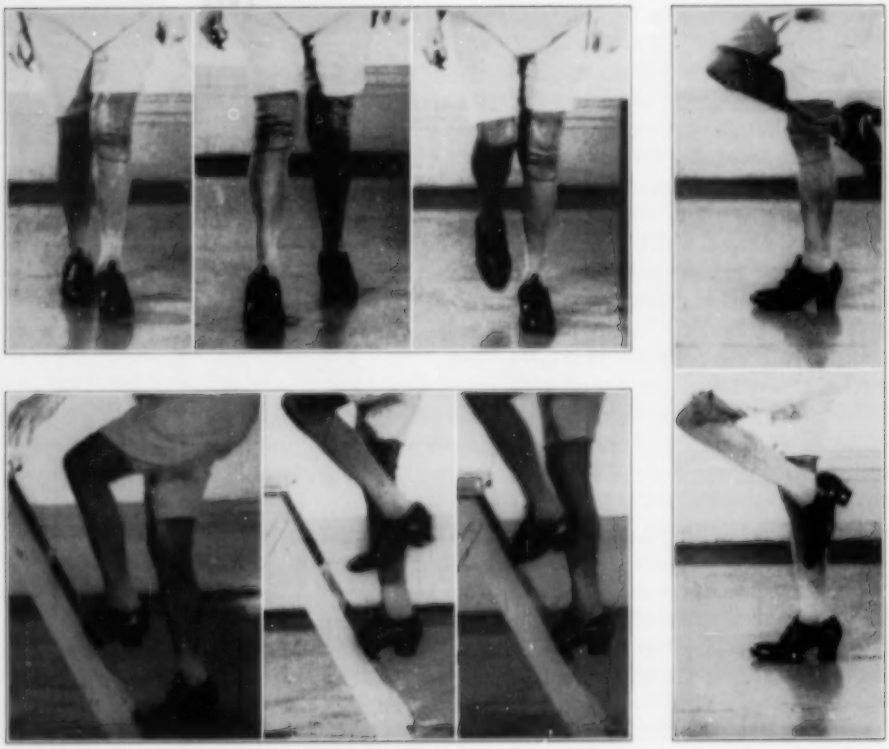

FIG. 10-C

Views from a cinema made five years after osteotomy, showing how active patient is.

FIG. 11-A

Mrs. W. Roentgenogram made before operation, showing gross bilateral osteo-arthritis.

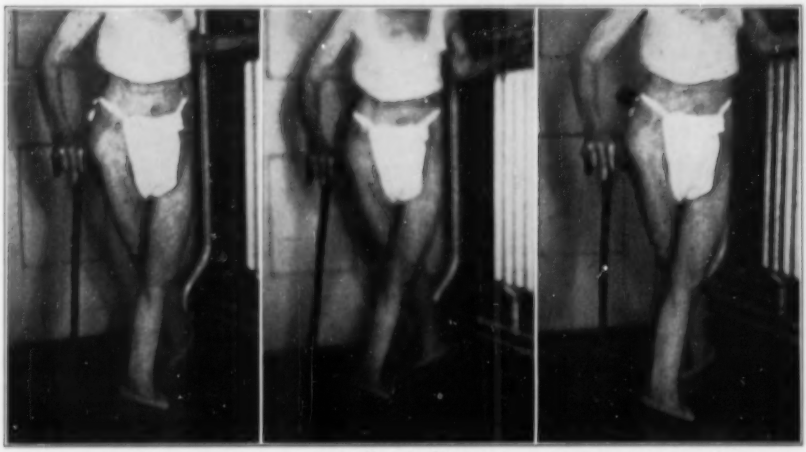

FIG. 11-B

Views from a cinema, showing the patient struggling against scissor-leg deformity and pathetically trying to walk.

The form of arthroplasty which I use at present is the replacement of the femoral head by a prosthesis of acrylic resin, commonly known as the "Judet operation". The value of this procedure lies not only in the retention or creation of movement, but also in an extremely short period of after-treatment, neither technically difficult nor tedious nor troublesome, and this renders the procedure attractive to the oldest patients in particular. It is true that I do not know how long the prosthesis or the acetabulum or both will stand the wear and tear of the use to which they are subjected, and I take care that the patients are well aware of this uncertain factor also. But it seems to most of them worth while to undergo the operation if thereby they gain reasonable activity and independence, and one,

FIG. 11-C
Roentgenogram made after a bilateral arthroplasty.

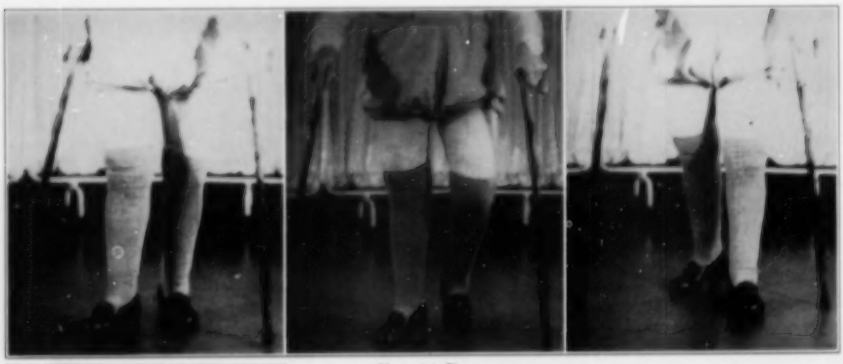

FIG. 11-D
Views from cinema, showing the patient walking.

two, three, or four years of freedom from pain. The bath chair, the bogey of old people, disappears from their conscious thought. The simplicity and speed of this arthroplasty has enabled us to relieve patients who otherwise might well have had to continue struggling to eke out their petty space of time. Take, for example, the woman of seventy-seven with very severe bilateral osteo-arthritis shown in Figures 11-A through 11-D; or again consider a man with gross Paget's disease (Figs. 12-A and 12-B), who had to give up his work because of arthritis with very bad pain and was totally disabled. The point about these two patients is that no other procedure would have been applicable. What else could have been done for these two people and others like them?

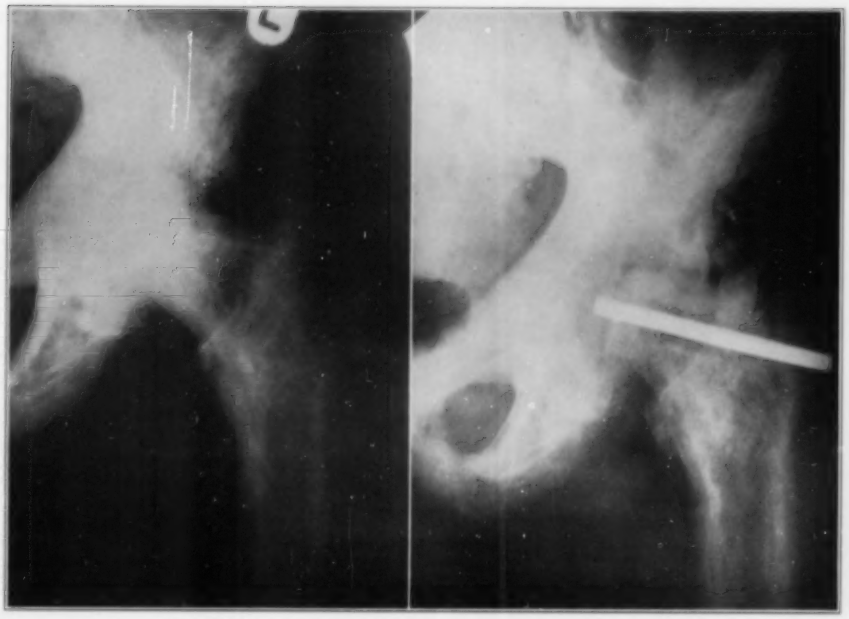

FIG. 12-A FIG. 12-B

Fig. 12-A: W. J., a patient with advanced osteitis deformans who was unable to work.
Fig. 12-B: After arthroplasty, the patient returned to his work as a garage mechanic.

Of course the results are not good in the absolute; they are not like the easy cases in which one obtains very good movement and almost normal activity.

I wish to say a word about technique. Having tried all approaches, I have now settled on the posterolateral, which is really a modified Kocher's approach. Instead of cutting across the glutaeus medius at the tendon or trochanter level, as Gibson does, I displace the glutaeus medius forward by shaving from the femur its tendon of attachment and the vastus lateralis fascia with which it is continuous. The glutaeus medius and the vastus lateralis form a moderate angle anteriorly, and so forward displacement is easy. In closing the wound I suture the tendon juncture to the quadratus femoris and the tendon of the glutaeus maximus. There is, therefore, no solution of the glutaeus medius in continuity, and its essential strong abductor force is unimpaired.

In arthroplasty, as in other major operative procedures, there must be a line of surgical retreat in the event of failure—what is sometimes called a "redemption procedure". Before I adopted the acrylic arthroplasty, I wished to be sure of such a line of retreat. I had already been performing on patients with complete ankylosis of both hips an arthroplasty which consisted of total excision of the head and neck, followed by an angulation osteotomy at the lesser trochanteric level. (Batchelor in London and Milch in New York appear also to have been using this operation.) I saw that this procedure could be successfully used if for any reason the acrylic arthroplasty were to fail. I have had occasion to employ this "excision-angulation" and I am satisfied with the result. Here is an example: A man aged sixty, an able-bodied seaman who had had to give up because of osteoarthritis, returned to his ship three months after the Judet operation (Figs. 13-A and 13-B). About four months later, he was caught in a storm at sea, was thrown from a ladder and fractured the neck of his femur and the stem of his prosthesis (Fig. 13-C). I removed this and the stump of the femoral neck and performed an angulation osteotomy (Fig. 13-D). In the film which accompanied this paper, he can be seen to walk and climb and jump (Fig. 13-E). Although he has not a perfect hip, he has a very useful one. He is now working

at the docks, but he wants to go back to sea again as soon as we have said he need not use a stick.

Finally, what of the future? It is clear that the application of arthrodesis is and will remain relatively limited; osteotomy appears irrational and its success is unexplained; the acrylic prosthesis may not last, and there may be nothing to take its place. I am convinced that we must forthwith try to get a better understanding of the origin of the pain in osteo-arthritic hips. It has been thought that the pain originates almost entirely in the

FIG. 13-A

FIG. 13-B

Fig. 13-A: R. L., a patient with osteo-arthritis (dysplastic hip).
Fig. 13-B: Three months after arthroplasty the patient rejoined his ship as an able-bodied seaman.

FIG. 13-C

FIG. 13-D

Fig. 13-C: The prosthesis fractured when the patient was thrown onto the deck in a storm.
Fig. 13-D: Roentgenogram made after removal of the prosthesis and performance of an angulation osteotomy.

FIG. 13-E

Views from the cinema. The patient is now working on the docks.

capsule and perhaps somewhat in the muscles, but the question haunts me as to whether there is not some source of pain in the bone itself.

Let us revert to the little lady of eighty-odd mentioned earlier in this paper. It will be remembered that, although there was no displacement at the osteotomy site, she was relieved of pain to a very surprising and remarkable degree. What was the cause of her relief? Is it not possible that nerve fibers permeating the bone along the blood vessels are divided at the same time as the bone, and so the path of pain is interrupted? It may be that in the osteo-arthritic hip there is a non-infective hyperaemic reaction inside the bone which is arrested by division of the bone (the immediate relief afforded by removal of the head in a fresh subcapital fracture of the femur may be on the same lines). Or it may be that the regenerative changes associated with healing cause some reversal of painful processes in the joint tissues. We might do well to think on these things. We might also do well to remember that the body normally expects the hip joint to be freely movable, stable, and painless, but that, when these qualities are lost and we have to decide which can be restored, freedom from pain comes first, then stability, and movement only third (unless of course it may rank equal with stability because of absence of movement in the other hip).

Moreover, I think that we must keep an open mind about the whole question of arthroplasty by present methods. We must remember that arthroplasty is not a new idea, and even the prosthetic type of arthroplasty is not new. Seventy-five years ago Gluck of Berlin used an ivory prosthesis to replace the head. Fifty years ago Robert Jones spoke of successful arthroplasties. Yet twenty-five years ago, in fact fifteen years ago, arthroplasty generally was in disfavor. It is well to remember these facts, and to remember also that bones and joints are only flesh and blood, and it is well to consider carefully what form of intervention they are most likely to tolerate. It seems to me most improbable that the present forms of arthroplasty will endure. It also seems to me, if I may say so

without disrespect, that the trend here in the United States toward bigger and better prostheses is wrong. Just as the basic idea of Lane plates lived on by changing toward the more natural, so will arthroplasties involving interposition of inert materials survive only if they also tend toward the more natural.

We must try to understand more of the nature of bone, and why the osteo-arthritic hip is so painful, and from that understanding may come the knowledge and skill to use materials or methods in harmony with, and permanently acceptable to, the body tissues.

And so I end this paper, not in an atmosphere of certainty and satisfaction, but on a note of inquiry and speculation. Where is the source of pain of osteo-arthritis? Does it originate entirely in the capsule and muscles as has been thought, or does it originate partly in the bone, so that prostheses, excision-angulation, and osteotomy succeed largely because the bone has been divided? Can we discover or develop materials which in constitution and in texture are compatible with living tissues? How can we devise methods which are not empirical as at present, but based on sound physiological knowledge? How can we ensure that our surgery will not abuse still further the wonderful tolerance of the human body and that it will conform with, and approximate to, the natural behavior of living things? I do not know.

DISCUSSION

DR. J. S. SPEED, MEMPHIS, TENNESSEE: I shall limit my remarks to reconstruction procedures for non-union or avascular necrosis, or both, of the femoral head, after fractures of the neck of the femur.

Before discussing the use of the prosthesis for the femoral head, it might be well to evaluate briefly the results which we have obtained by the methods previously in use.

In 1952 Boyd and Brindley[b] reviewed the results obtained by various surgical procedures in 147 patients with ununited fractures of the femoral neck, who had been traced sufficiently long for end-result evaluation.

In the group of reconstructive operations, such as the Whitman, Albee, and Colonna procedures in which the femoral head was removed, results were considered satisfactory in 58 per cent., but limitations of functions were present which were far from desirable.

Osteosynthesis (bone-grafting without an osteotomy) was successful in 69 per cent. of the cases, but the late results in many of this group were unsatisfactory because of degenerative changes in the femoral head. High osteotomies with medial displacement of the shaft of the femur (McMurray osteotomies) resulted in union both at the fracture site and at the site of the osteotomy, but again, in many of those patients who originally had a good result, disabling degenerative changes in the femoral head later developed. As a whole, results in this group were disappointing and the operation was abandoned in favor of the angulation or valgus type of osteotomy.

High osteotomies described by Schumm[f] and by Dickson[c] or low osteotomy of the Schanz[e] or the Blount[a] type, where the inclination of the femoral neck is changed to a coxa valga position, gave the highest percentage of union and the lowest percentage of degenerative changes in the head of the femur. The addition of a bone graft, as advised by Phemister[d], aids in revascularization of the femoral head.

The results in the group in which a valgus type of osteotomy had been used have been so satisfactory that we prefer this operation to the use of a prosthesis in cases in which there is adequate neck and salvage of the femoral head appears possible.

It is obvious from this review that there is need for improvement in the results which we are attaining in the treatment of ununited fractures of the neck of the femur. In older patients with debility, pain is often

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(*Continued on page 500*)

TWO AND A HALF YEARS' EXPERIENCE WITH A VITALLIUM INTRAMEDULLARY HIP PROSTHESIS *

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From the Orthopaedic Service, St. Luke's Hospital, New York

Since the introduction of prostheses into hip surgery several years ago, various models involving different mechanical principles have been employed to solve essentially the same problem. Warnings against their indiscriminate use have been sounded, and many surgeons have awaited the passage of a few years to see how the various prostheses behave in the human body. The following report is of thirty-five consecutive cases in which one type of Vitallium intramedullary hip prosthesis has been used over a period of two and a half years. It is believed that valuable information can be obtained from a study of this small number of cases.

CHOICE OF METAL

Vitallium was selected as the metal of choice because of its long-proved ability to remain absolutely unchanged within the body. This assurance is lacking in steel, in acrylics, and in nylon. The hardness of the metal excludes the factor of wear and tear. It can be sterilized under steam pressure. The problem of breakage, which is a possible factor with any material selected, is counterbalanced by the engineering design of the prosthesis and the thickness of the metal to withstand the stresses involved.

SHAPE OF THE PROSTHESIS

The shape of the prosthesis is similar to the normal shape of the head and neck. It no longer contains the anteversion which was believed to be essential four years ago (Fig. 1). The curve of its long stem makes it easy to insert through either an anterior Smith-Petersen or a posterior Gibson incision. Its adequate head and neck length prevent an abductor lurch resulting from an insufficient glutaeus medius mechanism. It can thus be used in patients with a short femoral neck or in those cases in which an existing femoral neck may have been absorbed in later months after operative insertion of the Judet type of prosthesis. It is a one-piece appliance and, therefore, cannot come apart within the body. The long stem extending down the shaft gives assurance that the prosthesis will not permit angulation into coxa vara unless the shaft fractures.

REACTION OF ACETABULUM TO PROSTHESIS

In those cases of non-union of the fractured neck in which a wide joint space was present at the time of inserting the prosthesis, careful observation of the thickness of the acetabular half of the joint space demonstrated that the Vitallium prosthesis does not erode the articular cartilage. The width of this cartilage remains essentially the same during the months following the operation. In these cases the bone immediately adjacent to the cartilage in the acetabular roof fails to show any condensation of the bone trabeculae indicative of excessive stress passing through this area of the bone (Fig. 2).

Those cases with a wide joint space, however, are less frequent than the cases showing some narrowing of the joint space at the time of operation. In this latter group a tendency to bone condensation or sclerosis in the acetabulum has been noted in the follow-up roentgenograms (Figs. 3-A and 3-B). This is at the point of maximum stress transmission through the acetabular roof. The majority of the follow-up roentgenograms showed some visible thickening and increase of the trabeculae in this area (Fig. 6) so that the total

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, July 1, 1953.

effect was one of minimal condensation, but this did not seem to produce symptoms (Fig. 4). In two of our cases, however, in which an arthritic joint was present and the acetabular cartilage at the time of operation was not reamed out, this condensation appeared very rapidly and was believed to be associated with the resulting pain. There has been no tendency for a slightly damaged, worn cartilage to become normal after insertion of the prosthesis.

When the acetabulum has been remodeled by scraping out of the cartilage, breaking through

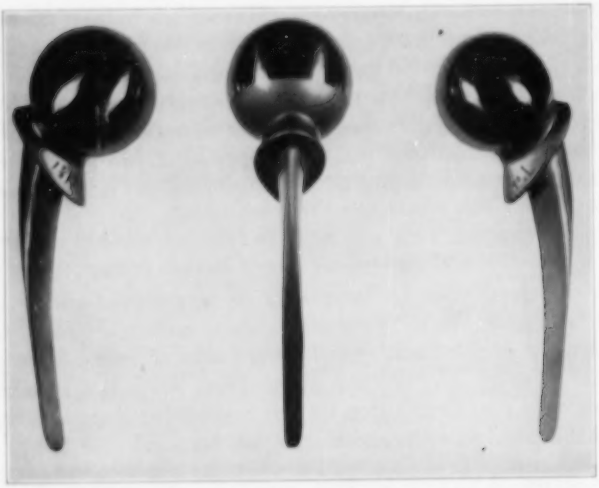

Fig. 1: Vitallium intramedullary hip prostheses are made in three sizes: one and five-eighths inches, one and three-quarter inches, and one and seven-eighths inches. The models on the right and left in this illustration contain anteversion. The center model has no anteversion curve of the stem and may be used in either hip.

Fig. 2: F. C. Roentgenogram made one year and seven months after operation. The acetabular portion of the right articular cartilage had not thinned since insertion of the prosthesis. No condensation was present in the acetabular roof. This represents the early type of prosthesis.

Fig. 1

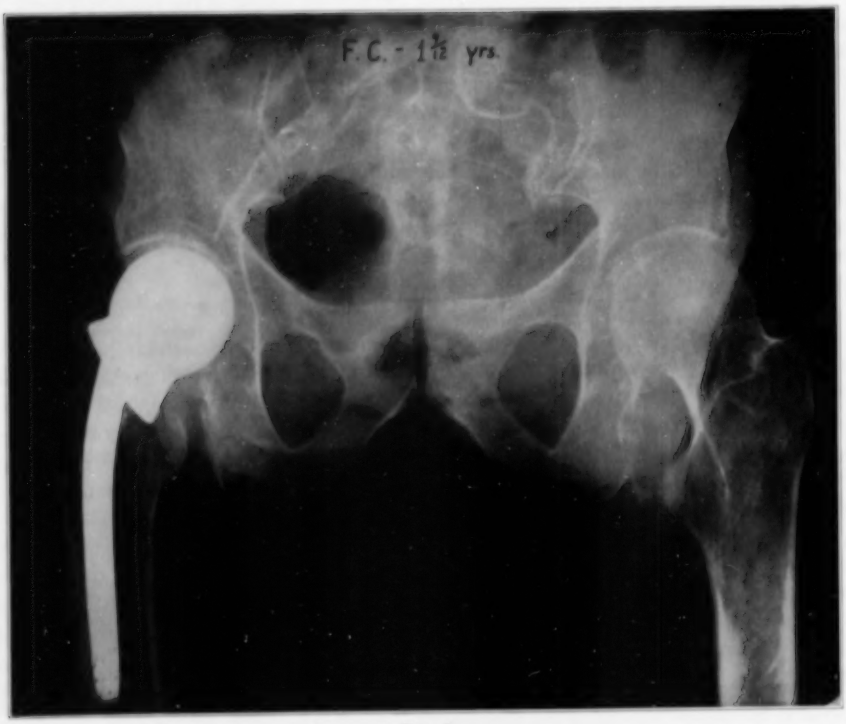

Fig. 2

the subchondral bony cortex with the gouge, and using the reamer to shape a new bony socket, a thin joint space is visible in the follow-up roentgenograms (Figs. 5-A and 5-B). This is the typical thin line customarily seen in cup arthroplasties between the cup and the bony socket. No tendency to form bone sclerosis or thickening and condensation of the trabeculae at the area of maximum stress transmission through the acetabular roof has been noted. It is realized, however, that not all such arthroplasties may be free of sclerosis in the future. Intrusion of the prosthesis further into the soft acetabular bone to form an Otto pelvis has not been noted, although this too may occur in the future.

The real significance of acetabular sclerosis is not understood. It is not believed to be a beneficial finding. Although the majority of patients with a hip prosthesis show some degree of it, the absence of the condition after arthroplasty would seem to indicate that we are not using a femoral head large enough to make a perfect fit. The sclerosis, when present in minor degree, does not seem to produce symptoms.

REACTION OF FEMORAL NECK TO PROSTHESIS

The prosthesis has been inserted in some patients in whom a small portion of the base of the neck was intentionally left intact. The follow-up roentgenograms revealed a slow absorption of this neck stump, so that the prosthetic collar settled down to form a broad contact base, extending from the medial side of the greater trochanter toward the base of the lesser trochanter and roughly corresponding to the intertrochanteric line. In other words, if a portion of the base of the neck is retained at operation, it tends to absorb to this basic line of junction between the shaft and the femoral neck. This has some significance when one considers the use of the Judet type of prosthesis in patients with a short femoral neck. While the absorption is probably due to circulatory changes, it may also be caused by basic stresses which are not understood. There is no doubt that long-standing cases of non-union after fracture of the femoral neck show a complete absorption of the neck down to this basic line of junction. The shape of the prosthesis was fashioned to take care of this anticipated absorption. In some patients with a generalized demineralization as a result of long-standing non-union, there has been some absorption of a decalcified calcar femorale. This absorption has not tended to be greater than five millimeters, and the process seems to become arrested when the density and strength of the bone increase with active use. It is possible for more absorption to take place. For this reason, it is wise to insist upon the use of crutches until satisfactory bone density is visible in the roentgenogram.

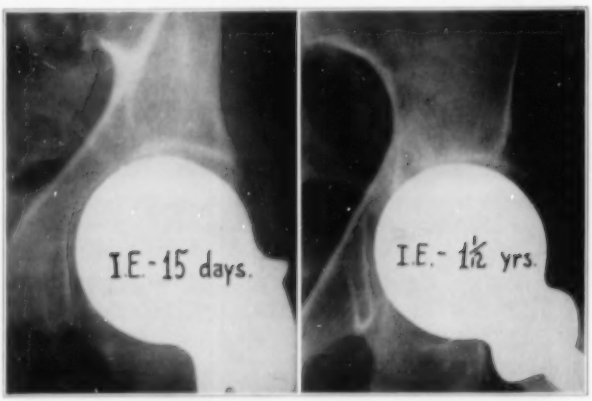

FIG. 3-A FIG. 3-B

Fig. 3-A: I. E. Roentgenogram made fifteen days after operation.

Fig. 3-B: After thirteen months the thin joint space was still thin, but sclerotic condensation had developed in the acetabular roof at the area of maximum stress. When he was last seen, the patient had no symptoms.

REACTION OF THE FEMORAL SHAFT TO PROSTHESIS

Within two months of the insertion of the prosthesis one can see in the follow-up roentgenograms a beginning increase in the calcium density of the bone near the lesser trochanter. This represents the calcar on which the juncture point of the prosthetic collar

and stem rest. This calcium density slowly spreads both medially and distally (Fig. 4). It is believed to be a beneficial finding and is considered to represent a further thickening of the bone trabeculae in this important area of the shaft through which the major portion of the weight stress runs. There is no tendency for the bone to thicken laterally at this level and neither increase nor decrease in the calcium density of the normal tension trabeculae is usually visible there. Many patients present a decalcified greater trochanter because of long periods of immobility or disuse of the abductor mechanism. If the greater trochanter is decalcified, it may take a year for the tension trabeculae to reach their normal calcium density.

The response of the medullary cavity to the tip of the prosthetic stem consists in a productive bone reaction which is best visible in a 15-degree external rotation view of the shaft. Here the bone tends to form a hook or curl around the tip of the prosthesis as if to fix it against the lateral femoral cortex. As monthly roentgenograms are made, this curl increases in density and finally firmly anchors the tip of the prosthetic stem against the lateral cortical shaft wall (Figs. 5-A and 5-B). In weight-bearing, the prosthetic stem pushes against the lateral shaft wall; the response of the wall to this stress is similar to that seen proximally near the lesser trochanteric region, where the calcar receives the major stress. The bone trabeculae thicken and become denser. The periosteum on the outside of the shaft in that area lays down more bone, so that the lateral cortical wall is actually thickened at least a millimeter or two. This favorable periosteal response extends from the level of the tip upward about five centimeters. There has been no evidence of erosion of the stem through the lateral shaft wall which would allow tipping into coxa vara. Some prosthetic stems have been driven through the walls of the femoral shaft during insertion. None have cut through at later dates.

FIG. 4

M. G. Roentgenogram made fourteen months after operation. The increased density of the calcar femorale is believed to be a beneficial finding. (Reproduced by permission of the Texas Medical Association from *Texas State Journal of Medicine*, **49**: 755, 1953.)

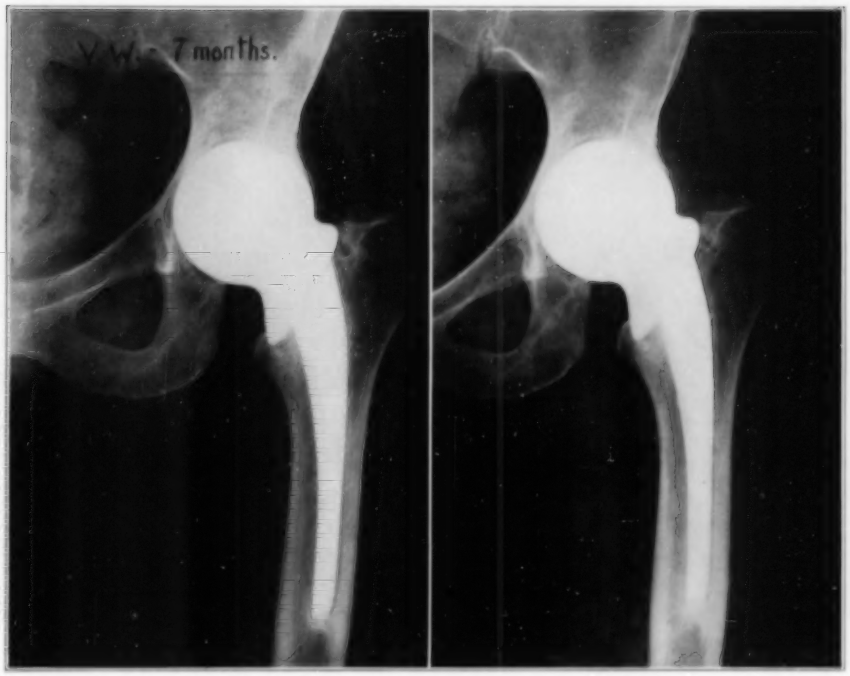

FIG. 5-A FIG. 5-B

Fig. 5-A: V. W. Roentgenogram made seven months after primary arthroplasty for destructive arthritis.

Fig. 5-B: Roentgenogram made one year after operation. The acetabular roof showed no condensation. The calcar and the femoral shaft showed a beneficial reaction to the prosthesis.

The prosthesis should be inserted snugly down the femoral shaft. In younger people the medullary cavity is narrower than in older people (Fig. 4). The prosthetic stem is loose in a wide shaft, and it may be some time before the curl of bone at the stem tip finally anchors the stem to the lateral cortical wall. There is some evidence to show that a fibrous band forms about the stem of the prosthesis shortly after its insertion, in the same manner in which a fibrous layer forms about an intramedullary nail. This band later calcifies. In not all patients, however, does the bone grow tightly about the stem. In some there is visible a definite hard, dense, bony cradle separated by a thin radiolucent line from the prosthetic stem, indicating that some toggle motion does exist. This is similar to the reaction seen about the loose stem of a Judet prosthesis which shows motion in the femoral neck. This cradle line of demarcation usually disappears in later roentgenograms, when the reparative bone has grown more snugly about the metal stem.

The final response of the femoral shaft to the prosthetic stem is a thickening of the medial wall at the level of the lower two inches of the stem. This seems to be a circumferential continuation of the sclerosing process begun on the lateral shaft wall (Fig. 6). It is a late finding and usually indicates that the prosthetic stem is firmly immobilized. The change was more apparent in our earlier cases, in which a larger, round-stemmed model was used. This reaction occurs later and is less pronounced in the present long, thin-stemmed model (Figs. 5-A and 5-B).

Low-grade infection produces a splotchy decalcification or pitting of the walls of the femoral shaft. This pitting in the beginning suggests a malignant condition or Sudek's atrophy. On the other hand, marked increase in the calcium density of both the medial and the lateral walls of the femoral shaft, which extended well below the tip of the stem

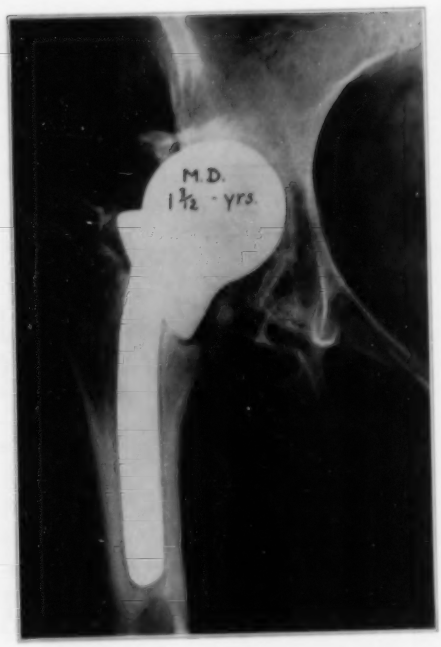

FIG. 6

FIG. 7

Fig. 6: M. D. Roentgenogram made fifteen months after operation. The old type of prosthesis had been used. A shelf-like spur had been left at operation to extend the roof of the socket.

Fig. 7: E. E. Pitting of the shaft was indicative of infection, in spite of the absence of fever.

in one of our patients with pain, suggested a similar low-grade infection without fever.

From a theoretical standpoint an ideal prosthesis would be one in which the bone grew so intimately around the metal of the prosthesis that the final result would be reinforcement of bone in the same fashion that concrete is reinforced. The placement of apertures in the prosthetic stem was considered but rejected, as from the engineering standpoint this would weaken by about 50 per cent. the stem of the model. Although it would be an advantage to have bone grow through these apertures at an early date and thus provide greater immobility to the prosthesis within the femoral shaft, the unavoidable hazard of ultimate breakage far outweighs this early advantage. Extracting such a broken stem would require decortication of a large part of the upper end of the femoral shaft, whereas, with the present solid stem, extraction would be relatively simple. In one known instance of a broken steel stem, a small cortical window cut near its tip allowed the broken stem to be driven upward with a Rush nail without too much difficulty. One personal observation and two cases in the hands of colleagues have confirmed the fact that these hip prostheses after six months were firmly anchored to the bone, so that they could not be tapped back out of the shaft. This does not mean that all prostheses become incorporated firmly into bone, but it does mean that the design of the prosthesis tends to allow this to occur.

INDICATIONS

The primary indication for the use of this prosthesis is non-union, in the aged patient, of a fracture of the femoral neck in which absorption of the neck has taken place. It is primarily a salvage appliance.

The second indication is its use in those hips painful because of aseptic necrosis of the femoral head after union of a fractured neck of the femur, in which the roentgenograms

still show a good acetabular socket and minimal arthritis. Such patients, however, are infrequently seen. Most patients with aseptic necrosis have not come to us until there has been considerable thinning of the cartilaginous joint space with associated arthritis. There is usually alteration in the contour of the acetabular socket, conforming to the deformed femoral head. These patients, in our experience, need some type of arthroplastic reaming out of the acetabulum in addition to the insertion of the prosthesis if subsequent pain is to be avoided.

The third indication for use of this prosthesis lies in that group with severe arthritis in both hips in which an arthrodesis of one hip is contemplated and some type of reconstructive procedure is needed for the other hip.

In fresh fractures of the neck of the femur, the use of the prosthesis is controversial. Although it has a place in isolated instances, such as in patients permanently confined to a wheel chair or in fractures resulting from radium necrosis, in general we still believe the procedure of choice is the insertion of a Smith-Petersen nail rather than the use of this appliance. It is our firm belief that successful nailing with satisfactory healing of the fracture gives a better result than can be obtained in most hips in which a prosthesis has been employed.

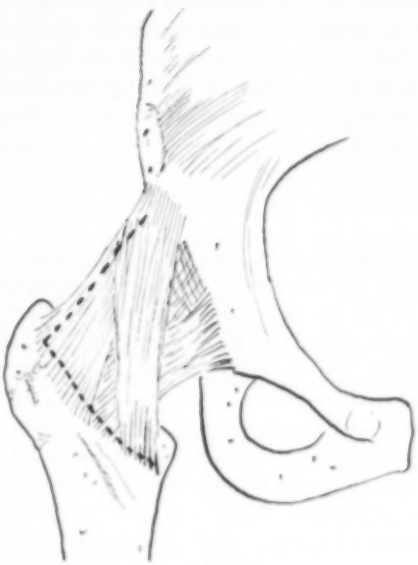

FIG. 8-A

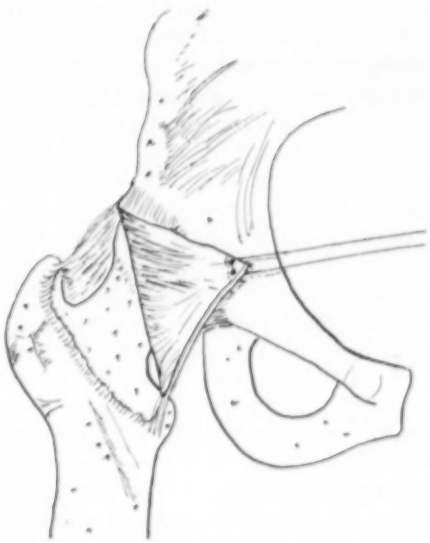

FIG. 8-B

The capsular incision should be L-shaped, beginning superiorly and angulating at the greater trochanter toward the lesser trochanter. This makes a large anterior flap. To gain length the capsule should be cut from the femur, not from the acetabular rim.

Primary arthroplasty with use of this prosthesis has been done in ten instances. The indications for such a primary arthroplasty are essentially the same as those for use of the Smith-Petersen cup. The author's experience still leads him to believe that a hip fusion is the operation of choice for a painful monarticular hip lesion in a young wage-earner for whom long hours of work are necessary. When arthroplasties are indicated, however, this prosthesis may be used. The simplicity of the operative procedure and the rapid recovery of function without the necessity of elaborate rehabilitation measures is striking. The results in this small group have been superior to other types of arthroplasty performed by the author.

OPERATIVE TECHNIQUE

The operation may be performed through an anterior Smith-Petersen incision or through a posterior Gibson approach. We prefer the anterior incision. The technique of operation has been described elsewhere [1, 2].

At operation the ascending branches of the lateral femoral circumflex artery are isolated and ligated. These arterial branches supply nourishment to the capsule and part of the neck of the femur. One need feel no qualms in ligating these, since it is planned to remove the femoral neck at its base and one need not be worried about its essential blood supply. We have noticed no ill effects after ligation of these vessels. If the neck is to be preserved when other types of prostheses are to be used, the blood supply should not be altered. This procedure, however, minimizes a considerable normal operative blood loss.

The method of opening the hip-joint capsule is believed to be of considerable importance, because of the danger of subsequent dislocation. The author is firmly convinced that the capsule should not be opened in the usual anterior manner. Dislocation usually occurs through external rotation of the femoral head, and it is, therefore, important to leave a firm anterior capsular flap to hold the head in the socket during external rotation. The capsular incision should be made superiorly (Fig. 8-A). Dislocation does not occur by displacement of the femoral head directly laterally and superiorly unless the distance from the dome of the head to the outer aspect of the greater trochanter is short. The prosthesis is long enough to prevent this. The capsular incision should begin at the superior acetabular margin and run directly laterally to the greater trochanter. It should then curve downward and medially toward the lesser trochanter. This L-shaped incision provides a large capsular flap to be retracted medially, exposing the hip joint (Fig. 8-B). It is later to be sutured firmly back into place, both superiorly and laterally, and is reattached to the upper fibers of the origin of the vastus lateralis. The capsule should not be excised except in unusual circumstances.

Since in nearly half the cases it is necessary to regain length, because of the shortening which results from overriding, this incision allows the capsule to be stripped from the femoral insertion both medially and posteriorly by the use of the periosteal elevator or by sharp dissection. It is usually necessary to divide the capsule by sharp dissection from the superior surface of the neck in the trochanteric fossa. This superior portion of the capsule is tight after a long interval of non-union and length cannot be gained unless the capsule is completely removed from its femoral attachment. The capsule should never be severed from the acetabular margin since dislocation may then occur, not immediately but months later, because of improper reattachment of the capsule to the acetabulum. Two instances of slow progressive subluxation occurred because of division of the capsule from the acetabular rim before this salient feature was realized. In one of these dislocation finally occurred. No subluxation has occurred in the later cases, in which the present technique of opening and suturing back the capsule was used.

Fracture of the femoral shaft may occur during insertion of the prosthetic stem into the medullary canal. The operator should fit the stem snugly into the canal by rocking the prosthesis from side to side while it is being pushed downward. It should not be driven home except for the last half centimeter. The usual blockage to firm, secure seating of the collar on the calcar is due to failure to remove the superior portion of the bony neck near the greater trochanter itself. Fracture of the shaft can also occur during reduction of the prosthesis into the acetabulum after it has been inserted. Reduction should always be attempted with the extremity held in marked external rotation, the assistant pulling distally on the limb while the operator pushes downward and inward on the prosthetic head from above. As the head "oozes" into the acetabular socket, the extremity may be internally rotated. Forceful internal rotation applied before this moment is apt to produce a serious shattering of the shaft.

COMPLICATIONS, THEIR PREVENTION, AND REDEMPTION PROCEDURES

Three main complications must be anticipated and avoided: infection, fracture, and dislocation.

Infection

The most serious complication is that of infection, since it nullifies the operation and requires ultimate removal of the prosthesis (Fig. 7). It is not believed that most infections are due to improper sterilizing technique, but to make certain that this hazard is not present the prosthesis should be autoclaved and not soaked in an antiseptic solution. Most infections are due to re-operation on a hip which has been operated upon once, twice, or even three times before. We have debated the advisability of extracting the Smith-Petersen nail several weeks before insertion of the prosthesis. Although we rigidly adhered to this practice in the beginning, we now are not confident that it makes any appreciable difference. When infection does occur, the best redemption procedure, after extraction of the prosthesis, is to place the greater trochanter into the acetabular socket in a fashion similar to the Colonna operation. If the prosthesis alone is removed, and the femur is allowed to seek its own level, the result will be a rather worthless lower limb in an adducted, externally rotated position. One needs the stability in walking which is afforded by placement of the greater trochanter in the acetabulum. One hopes, of course, that this Colonna procedure will result in solid fusion.

Fracture

A danger which cannot be stressed too strongly is fracture of the femoral shaft. This may occur from hammering the prosthesis down the femoral shaft and thus splitting the shaft walls, or it may occur during attempts to place the inserted prosthesis into the acetabular socket. The latter is more common, either because too much neck has been left so that the part is too long, or because the limb has become short from overriding and the capsule has not been freed from the trochanteric region, so that there is not sufficient laxity of structures to permit restoration of length. Often the femoral shaft is decalcified and will break easily. One major fracture occurred in our series. It was handled by a primary hip fusion, with use of iliac-bone strips taken from the same side. A colleague in another hospital successfully managed this same complication by the use of a Parham band which held the fractured pieces about the prosthesis. With the aid of a hip spica, union was achieved.

If full length cannot be obtained by capsular division, more of the calcar needs to be cut off and shortening must be accepted as a compromise. After the prosthesis has been seated well into the femur, the operator should place a finger in the acetabulum to see if vigorous traction of more than an inch is still necessary in order to place the metal head into the acetabulum successfully. If so, the prosthesis should be withdrawn and more of the calcar should be removed, until the same test shows that less than a centimeter of traction will be necessary to pull the dome of the prosthesis down to the proper level of insertion.

Minor fractures of the shaft have occurred while the prosthesis was being driven into the medullary cavity. This should be avoided, since such fractures may be enlarged during attempted reduction. Such minor fractures, if noted in the roentgenograms made on the operating table, usually heal if the extremity is supported in gentle Russell traction during the succeeding weeks. Weight-bearing should not be permitted until the fractures have healed. One minor fracture occurred in our series, which successfully healed under this regimen.

Dislocation and Subluxation

Early dislocation of the prosthesis from the hip socket may be due either to excision of the capsule in a mistaken endeavor to rid the patient of the pain-conducting fibers of

the capsular nerve supply or to improper capsular incision or release as already described. While excision of the capsule is necessary in some arthroplasties for arthritic hips, these patients need immobilization in plaster boots, with the extremity in abduction and internal rotation, or in a spica if the formation of a new acetabulum has not created a deep and secure enough socket for the head.

Late subluxation occurred in two cases in our series over a six-month period and in one of these progressed slowly to dislocation. Both of these hips had rather extensive capsular division from the acetabulum through an anterior incision. The resuturing of the capsule was not secure enough to anchor the capsule firmly to the acetabulum. In one of the two, 3.1 centimeters in length was gained to offset the shortening which resulted from overriding in non-union of the fractured neck of the femur. At re-operation for dislocation, a shelf stabilization was necessary after the acetabular socket had been reamed out. This successfully kept the prosthesis in the new acetabulum and resulted in stability and a satisfactory hip. The second patient is still asymptomatic and surgery is not warranted, although roentgenograms reveal that the prosthetic head is teetering on the outer margin of the acetabulum.

Since care has been taken in later operative cases to make a superior instead of an anterior capsular incision, no subluxation has occurred. We believe the superior capsular incision to be of definite value in preventing this rather common complication.

Wrong Track

A minor complication and a trap easy to fall into is allowing the prosthetic stem to pass out through the old Smith-Petersen nail hole, just below the greater trochanter, during the attempt to insert the stem into the medullary cavity of the femur. This complication may be noticed when it is found that the prosthetic collar does not rest properly on the stump of the severed neck. It is best guarded against by making a lateral incision to extract the nail; this is preferable to extracting it by retracting the tensor fasciae latae laterally through the anterior incisional wound. One can then insert the index finger and feel the prosthetic stem pass out through the shaft wall instead of going down the intramedullary canal. Following a fixed rule of making roentgenograms at the completion of operation will ensure the proper seating of the prosthesis.

RESULTS

The results in the thirty-five patients in whom this prosthesis was used must be discussed from several important standpoints. There were two cases of infection, one of which occurred immediately, necessitating removal of the prosthesis. This was a frank failure. In the second case the infection was so low-grade that the prosthesis was not removed until eleven months later. This, too, was a failure. There was one severely fractured femoral shaft which was considered an operative failure, but a successful arthrodesis was achieved nevertheless, allowing painless, stable weight-bearing. In a fourth case a slowly progressing subluxation developed which required re-operation with shelf stabilization; this resulted in a stable, relatively painless hip with definite limitation of motion. The fifth patient, who also had a slowly developing subluxation, still is satisfied with her result and does not wish surgery.

These five cases must be omitted from averaging the results in terms of pain, motion, muscle power, and the use of canes and crutches, since they represent frank failures in operative technique and do not represent necessarily what is to be anticipated normally from the use of this prosthesis. By the same token, those patients with arthroplasties had more motion after operation than they had had originally, and their results as regards motion should not affect the average of motion of the other groups. We could not anticipate that the prosthesis would result in more motion than had been present before operation in every case.

Pain

If the five cases mentioned above are omitted, pain may be evaluated in thirty patients. The pain was so great in two of these that the operations must be considered unsuccessful. Both represented instances of aseptic necrosis of the head of the femur with associated acetabular arthritis. The prosthesis had been inserted without a primary arthroplasty of the acetabulum and without reaming out of the degenerated, friable articular cartilage to form a new socket. The failure to obtain relief of pain in these two cases was believed to be due to the insufficiency of the arthroplasty, since other patients with a proper reaming out of the articular cartilage have obtained painless hips. The remaining twenty-eight patients have been satisfied with the relief of pain obtained. Three of these occasionally have enough pain to consult the author, but are definite in their statements that the major portion of the pain is relieved. The remainder of the twenty-five patients have been completely relieved of their pain.

Hip Motion

An evaluation of the hip motion in the thirty patients under discussion must be made in three separate categories:

1. Patients with early non-union, without shortening, in whom the necrotic head had been removed and the prosthesis had been inserted without extensive capsular division have regained full range of motion of the hip joint. All the patients in this group are able to flex their hips to a position of 45 degrees, to extend them fully, and have essentially normal internal and external rotation. This motion is classified as excellent and the control of the limb in these patients is excellent.

2. In those hips in which extensive capsular division had been necessary to gain length, because of overriding and shortening, motion is not so complete as in the first group. These have usually had an associated arthroplasty or reaming out of the acetabulum because of degenerative arthritis. Five of the seven patients have flexion of more than 90 degrees. They have some limitation of internal rotation and of abduction. They are able to sit normally and to handle their extremities without too much stiffness. Two patients have difficulty in putting on their shoes and stockings.

3. In all those cases in which arthroplasties have been done for a primary degenerative condition and in which pain and limitation of motion were present before operation, motion has been greater after insertion of the prosthesis. In these, flexion has usually been slightly more than 90 degrees, with good internal rotation and limited external rotation and abduction. These patients definitely have increased their range of motion and control of the limb since the one-year follow-up milestone.

Two patients with aseptic necrosis did not have an arthroplasty at the time their prosthesis was inserted. Their motion is poor because of pain and spasm.

Muscle Power

In no case has muscle power returned to normal. Although stability is present in these hips and there is no positive Trendelenburg sign or an abductor lurch, the muscle power still has not been noted in a single case as being normal. The power of hip flexion and extension is sufficient to sustain body weight in climbing or descending stairs. The chief deficiency in muscle power seems to be in the abductors and it takes well over a year for the patient to hold the abducted extremity elevated above the table without tilting his pelvis.

Use of Canes and Crutches

At the time of writing only five patients are able to walk without crutches or a cane. This has been a most discouraging factor to the surgeon, but it does not represent a disap-

pointment of magnitude to the patient. Most patients seem perfectly capable of walking across the room without a cane. They state, however, that they do not feel secure without one and still wish to use it as an everyday practice of safety. Crutches are insisted upon for a period of nine months until the femur has regained strength and has become well mineralized. The few patients under forty-five years of age gain the ability to walk with a cane earlier than the aged and are the first to walk without support. Since the strength of these hips seems to improve well into the second year after operation, it can be expected that more patients will be able to walk without canes or crutches at a later date.

Deaths

There have been no deaths attributable to the operation. One patient of ninety-two years died four months after she had become ambulatory. One patient whose fracture was due to radium necrosis died from metastatic disease of the cervix after nine months.

Fracture of Prosthesis

Fracture of the prosthesis has not been encountered and has not been reported to the manufacturers.

CONCLUSIONS

This prosthesis offers valuable salvage possibilities. Its use as a primary arthroplastic procedure gives promise for the future. Complications encountered early in the series have taught us pitfalls to avoid and our five technical failures should serve as valuable lessons in the use of the appliance. Two years' experience give little cause for fearing that the body will not tolerate the prosthesis. A viable head after a successful nailing, however, is still a more desirable result.

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DISCUSSION

(Continued from page 488)

the major complaint and the only one which is of any real importance to them. For these the hip prosthesis offers a quick and relatively safe solution. In younger patients, in whom resumption of active function is the major consideration, the prosthesis or Vitallium-cup arthroplasty is certainly indicated if the head shows well established avascular changes or excessive demineralization and absorption.

We are honored to have Prof. d'Aubigné with us today and are indebted to him for the sacrifice he has made to come here to share with us his vast experience in the use of the femoral-head prosthesis. We are impressed, not only by the excellence of the results he has obtained in this new field of surgery, but by the great importance he attaches to the principle of obtaining anatomical and mechanical restitution of the components of the hip joint. In order to attain this, the surgical approach must provide adequate exposure of the acetabulum and the femoral head and neck.

Prof. d'Aubigné emphasizes the necessity of restoring the normal length of the neck by a cervico-capital prosthesis when the neck is short and he reports that, in his early cases, in which this was not done, 56 per cent. of the results were fair or poor.

His careful analysis of the stages of functional adaptation of the hip to the prosthesis should be a valuable guide in evaluating our own results. It is important to know that during the first year the functional result is largely dependent upon the mechanical restoration of the components of the hip joint. In the second year adaptive changes occur which may either impair or improve the function. After the second year a *status quo* is usually established and the hip changes very little, except in that relatively small group of cases in which deterioration continues and failure occurs.

I am certain that the femoral-head prosthesis is a valuable addition to reconstructive surgery of the hip and that further experience will establish both the indications and the contra-indications for its use. I wish again to express my own appreciation and that of our Association to Prof. d'Aubigné for his excellent presentation.

Dr. Thompson's paper expresses sound thinking and there is nothing in it with which I can disagree. We all appreciate the many helpful suggestions which help to simplify the operative technique and to avoid accidents which impair the functional result.

We have used the Thompson prosthesis in all cases of non-union in which the neck was short. The results have been so satisfactory that we are planning to extend its use.

Medical history shows that, whenever a new medicine or a new surgical procedure is introduced, there is an inevitable tendency to extend the indications for its use to conditions for which it had never been intended. This applies particularly to the use of the hip prosthesis in the treatment of fresh fractures of the femoral neck. In 60 per cent. of our cases of fresh fracture of the neck of the femur there was union with a living head and an essentially normal hip. The functional capacity in this group could not have been achieved by any type of reconstruction procedure or prosthesis. No type of treatment should be used routinely which deprives a patient of the opportunity of such a favorable outcome. Use of the prosthesis in fresh fractures should be restricted to exceptional cases until we are able to predict with reasonable certainty which cases are doomed to that group of 40 per cent. in which avascular necrosis develops, or non-union, or both. The specter of non-union and avascular necrosis in 40 per cent. should not make us forget the 60 per cent. of normal hips.

There is at present no practical method of determining the residual amount of blood supply to the femoral head at the time of the fresh fracture. Much experimental and clinical research with radio-active phosphorus (P^{32}) is being carried out to answer this question.

I am more familiar with the work of Dr. Harold Boyd who is exploring the clinical phase of the problem. He is endeavoring to work out a practical method of determining the amount of blood supply to the femoral head at the time of the primary treatment, so that we may have some reasonably dependable standard on which to base a prognosis as to the fate of the femoral head. This should be a helpful guide in determining the method of treatment to be employed.

Radio-active phosphorus (P^{32}) is injected intravenously two hours before the nailing of the fresh fracture. At the time of nailing, relative counts are made by means of a Geiger counter introduced first into the femoral head and then partly withdrawn; a second count is made in the greater trochanter, the standard ratio between these counts having previously been determined on the basis of normal hips. A decrease in the normal ratio of the head count to the trochanteric count indicates an impairment of the blood supply in the femoral head, either partial or complete, depending on the variation of the ratio.

The results so far have been sufficiently consistent to make us believe that this procedure may become a practical method of measuring the blood supply in the femoral head and predicting its probable fate. A large series of cases will have to be studied in which the variations in the ratio of the head count and the trochanteric count and the predicted fate of the head are correlated with subsequent clinical observations. If these are in agreement, the method will be of practical value.

Dr. Harry Winkler, Charlotte, North Carolina: In our own clinic we have had experience in operating on about sixty hip joints in which we used various types of prostheses; the average follow-up period was eighteen months. We feel that this comparatively new procedure offers the only helpful solution to certain difficult problems in the hip joint. In one patient, a colored housewife with osteo-arthritis of the hip, a Smith-Petersen cup arthroplasty had been attempted. For this we substituted a Judet prosthesis. The patient has been followed for more than eighteen months; she is walking well and doing all of her housework, including heavy laundry for the family. In another case the preoperative roentgenograms showed bilateral osteo-arthritis, and cup arthroplasties were performed. Absorption of the neck began to take place in the left hip; the patient complained of persistent pain in this hip and requested removal of the cup, which was done. Her relief was so great that we also removed the cup from the opposite hip, again at the patient's request. (Dr. Winkler then projected a slide showing the left hip after introduction of a Judet prosthesis into the narrow nub of the neck which was revealed following the mold arthroplasty.)

Dr. Fremont A. Chandler, Chicago, Illinois: In my observations of prostheses in the hip I have found the push-pull technique of making roentgenograms most useful. Such roentgenograms reveal movement between the prosthesis and the bone structure, whereas single roentgenograms do not. I should like to urge that more thought be given to the employment of this technique.

I wish to raise another point which I feel contributes to a better understanding of pathological changes in the hip joint. This is the concept of "coronary disease of the hip" which I set forth several years ago.[a]

a. Chandler, F. A.: Coronary Disease of the Hip. J. Internat. Coll. Surg., **11**: 34–36, 1948.

In this paper, attention was drawn to the similarity between the circulation of the femoral head and that of the heart. Each structure is supplied by end arteries which protrude into the synovial structures of the joint in the case of the femoral head and into the pericardium in the case of the heart. The term "coronary" is confined to the heart only by usage. "Coronary" means crownlike or encircling, a term which describes the circulation both of the heart and of the femoral head. If this concept is kept in mind in the treatment of the various conditions of the hip, a clearer insight into the pathological changes will result.

Dr. Leonard T. Peterson, Washington, D. C.: Having previously reported on the use of the Collison prosthesis, I wish at this time to endorse the Frederick Thompson type of prosthesis which I have used exclusively for the past fourteen months. It is an excellent prosthesis and simpler in application. In a series of sixty-five hips, we have inserted the Thompson prosthesis in twenty-five, and we have been particularly pleased with it. Dr. Thompson will probably agree that one can dispense with the models for the right and left side and use only the standard model.

In our series about twenty fresh fractures are included. In twelve of these the Thompson prosthesis had been inserted and it was found that its usefulness was greatest in these fresh fractures.

Dr. Paul Steele, Pittsburgh, Pennsylvania: We were very enthusiastic about these prostheses and used them in seventy-eight patients. Seventy-five of these have pain; they also show limitation of motion, thickening, and various other undesirable features. Perhaps this was due to our methods; at any rate, I have seen only one good result in this series. I have followed all of these patients; they have a fair range of motion, they use their hips all the time, they have a little difficulty in walking at night, but they all have Charcot hips.

Prof. d'Aubigné (closing): The fourteen dislocations in our series occurred only in the first two years. In the last three years, during which we performed 300 operations, we had no dislocations. Patients come to us from many countries for this operation and this accounts for the large number in our series. Often they are sent by other patients. I would say that 75 per cent. of our patients are very happy with their results. They are doing very well and are walking without a limp and without a cane. I do not think that these facts can be completely disregarded, as many of these patients had been crippled and needed help. That is the reason I believe in these prostheses. We must learn through experience when to use them and when not to, and that is what I have been trying to do.

Prof. McFarland (closing): I am glad that the presentation of these papers gave so many people an opportunity to discuss their own results. It is not difficult to present a large number of patients who are satisfied with their operations. I want to make it quite clear, however, that I have an open mind on these procedures and I hope that eventually we will find something very much better.

Dr. Thompson (closing): I firmly believe that the appliance which I designed should be used only as a salvage procedure. Unfortunately we see many patients with non-union in whom a Dickson type of osteotomy is not possible. We have performed Dickson osteotomies and have achieved what we thought were excellent surgical results; union was obtained, but aseptic necrosis later ensued. In others the slipping, displacement, and shortening were so great that this osteotomy was not feasible. It is primarily in such cases, when there is absorption of the neck and overriding of an inch or an inch and a half, that this appliance offers valuable salvage possibilities. I must again stress the fact that in such cases the capsule must be loosened from the femur and not from the acetabulum. In order to gain the length necessary to perform a proper salvage procedure, one must release the capsule. We have found that this is somewhat easier to accomplish through an anterior incision.

REGIONAL STRESS ANGIOGRAPHY OF THE HIP

A Preliminary Report *

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The following study of regional stress angiography of the hip was undertaken as a means of visualizing a suspected diminution in blood supply which may result from placing the limbs in the "frog-leg position". The frog-leg position is commonly used to maintain the reduction of a congenital dislocation of the hip. In this position the hips are held in abduction of approximately 90 degrees, flexion of 90 degrees, and external rotation of 90 degrees.

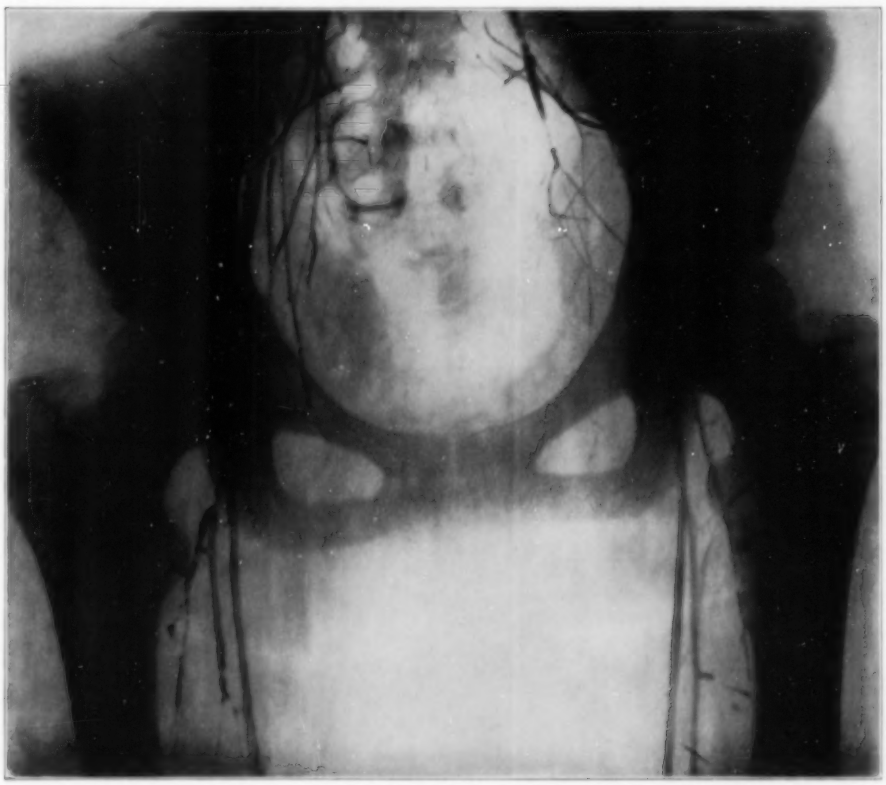

Fig. 1

Case 1, a girl, eleven years old. The cause of death had been acute glomerulonephritis, with hypertension before death.

The right lower limb was held in the "frog-leg position". The abdominal aorta was injected above the bifurcation. The pressure used was 120 millimeters of mercury.

It appeared that the position of the right limb interfered with the entrance of the injection substance into both the medial and the lateral femoral circumflex arteries, and the profunda femoris was poorly filled. The obturator arteries were not well visualized in this roentgenogram.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1953.

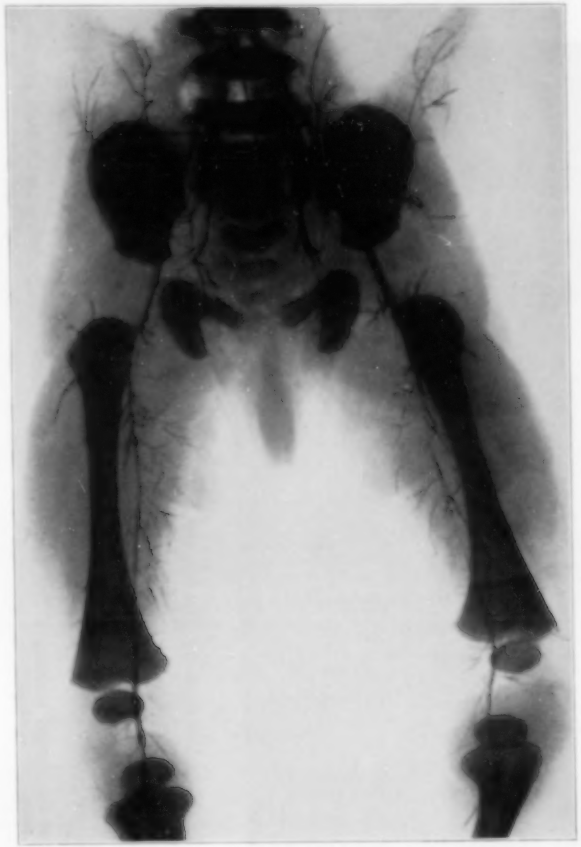

FIG. 2

FIG. 3

Fig. 2: Case 3, a girl, four days old. The cause of death had been bronchopneumonia.

There was not much muscle resistance to the frog-leg position (on the left). The pressure was 140 millimeters of mercury.

It was believed that, because the injection pressure was forty to fifty millimeters of mercury above the mean arterial pressure during life and because the muscle resistance was weak to abduction, no real difference in filling between the two sides could be determined in the roentgenogram.

Fig. 3: Case 4, a boy, eight years old. The cause of death had been leukaemia.

The postmortem rigor was quite marked; the adductors were very prominent at the limit of abduction. The right extremity was abducted during the injection. The injection pressure was sixty-two millimeters of mercury.

In the presence of marked adductor resistance there was an obvious lack of arterial filling of the extremity held in the frog-leg position.

Avascular necrosis of the femoral head has been a common complication after reduction of a congenital dislocation of the hip. Necrosis of the femoral head has also been observed as a complication in the normal undislocated hip after a period of fixed abduction of the lower extremities [2].

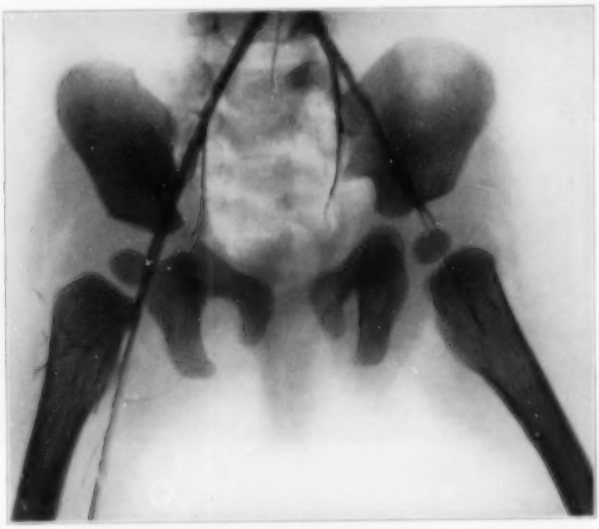

FIG. 4

Case 5, a girl, ten months old. The cause of death had been pulmonary oedema following a transfusion.

The left hip was brought to the frog-leg position against moderate adductor resistance. It was then injected at a pressure of seventy-eight millimeters of mercury.

There was almost no injection substance in the left hip. The femoral artery was very poorly visualized distal to the origin of the profunda artery.

Numerous studies have been made of the circulation to the femoral head. These studies have been based on direct visualization after injection of local arteries and on angiography. A qualitative determination of circulation to the femoral head has been aided by cross-section studies after selective ligation of the arteries. The arterial injections, as far as can be determined, were done on dissected specimens with the hips in nearly anatomical position, that is, in extension of approximately 180 degrees, with the lower extremities parallel to the median line and the same degree of external rotation.

It was stated by Tucker in 1949 that the tight adductors of the hip were the chief offenders in whatever circulatory impairment the frog-leg position entails. Our study was directed toward a comparison of the frog-leg position alone and the frog-leg position combined with adductor tenotomy in their effect upon the arterial supply to the hip.

The method used in this investigation was the injection of fresh autopsy material for angiography. In all of the cases, injections were performed within twenty-four hours after death.

The medium injected consisted of a mixture of barium sulphate and lead chromate suspended in a 10 per cent. solution of vinylite (copolymer of acetate and chloride) in acetone [1]. The abdominal aorta was cannulated as high as possible above its bifurcation. (This was important in order to assure equal pressure in the common iliac arteries.) The arterial tree was flushed, first with water and then with acetone. The pressures used for flushing and injecting were gauged by a mercury manometer. Arbitrarily, the pressure chosen for injection was somewhat close to a mean arterial pressure during life; the flushing was done at a pressure of ten to twenty millimeters of mercury higher than the injection. The apparatus used contained a substantial hydraulic reservoir to maintain approximately uniform pressure throughout the procedure.

The vinylite mass hardened within three to five minutes after injection. The limb or part could then be moved for roentgenographic examination without the risk of disturbing the amount of localized injected material.

The experiments were divided into two sections. In the first part the injections were made into the abdominal aorta while one hip was held in the frog-leg position and the other in the neutral position. After sufficient time had elapsed for the injected mass to set,

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 6, a girl, five months old. The cause of death had been congenital heart disease.

Both extremities were placed in the frog-leg position. There was moderate adductor resistance; in the last five degrees of abduction the adductors were taut and prominent. A subcutaneous tenotomy was performed on the left side. The frog-leg position was maintained until the injected material had set. The injection pressure was seventy millimeters of mercury.

Fig. 5-B: The left side showed heavier and more complete arterial tracings than the right. Although the femoral artery was visualized coursing down the extremity on the right, non-tenotomized side, the hip was conspicuously avascular. The appearance of the non-tenotomized side was comparable to that after injection with a single extremity in the frog-leg position, as in Cases 1, 4, and 5.

both extremities were placed in the anatomical position for x-ray examination. In the second part of the experiment both extremities were held in the frog-leg position, and a subcutaneous adductor tenotomy was performed on one side. The injection into the abdominal aorta followed the adductor tenotomy. The roentgenographic examination was made with the lower limbs in the anatomical position. Subsequently it was found that better visualization of the arteries was obtained when the limbs were internally rotated during the x-ray examination.

Eight cadaver injections were made by Dr. Kopell and Dr. Mattei. Of interest, but not entering into the compilation of results of this study, are six additional cadaver injections made by two residents. These are represented in Table I, Cases 9 to 14. In this

TABLE I

RESULTS OF ANGIOGRAPHY WITH ABDUCTION STRESS ON THE HIP JOINT

Case No.	Sex	Age	Cause of Death	Time between Death and Injection (*Hours*)	Abducted Hip	Adductor Tension	Tenotomy	Pressure (*Millimeters of Mercury*)	Remarks	Result
1	F	11 years	Glomerulo-nephritis	8	Right	Taut	No	120	Less filling on right.	Positive
2	F	1 month	Undetermined	4	Left	Poor	No	44	Pressure low. Less filling on left.	Positive
3	F	4 days	Bronchopneumonia	6	Left	Poor	No	140	Pressure high. Bilateral filling.	No contrast
4	M	8 years	Leukaemia	15	Right	Taut	No	62	Pressure low. Less filling on right.	Positive
5	F	10 months	Pulmonary oedema	5	Left	Taut	No	78	Poor filling on left.	Positive
6	F	5 months	Congenital heart disease	10	Bilateral	Taut	Left	70	Less filling on right.	Positive
7	M	1 day	Tracheo-oesophageal fistula	4	Bilateral	Taut	Right	54	Less filling on left.	Positive
8	M	1 day	Erythroblastosis foetalis	5	Bilateral	Taut	Right	50	Poor filling on left.	Positive
Abducted Hip with Straight Knee										
9	M	13 months	Bacterial pericarditis	4	Left	Taut	No	110	Less filling on left.	Positive
10	F	2.5 years	Congenital heart disease	6	Left	Taut	No	100	Left limb internally rotated.	Positive
11	M	5 weeks	Congenital heart disease	4	Left	Poor	No	70	Small child (6 pounds).	No contrast
12	F	1 day	Peritonitis	4	Bilateral	Taut	Left	150	Abduction increased after tenotomy.	Reversed
13	F	4 weeks	Meningitis	5	Bilateral	Taut	Left	115	Abduction increased after tenotomy.	Reversed
14	M	12 years	Lymphocytic leukaemia	6	Bilateral	Taut	Left	140	Slightly better filling on left.	Positive

FIG. 6

FIG. 7

Fig. 6. Case 7, a boy, one day old. The cause of death had been a tracheo-oesophageal fistula.
Both extremities were placed in the frog-leg position. The adductors were taut and prominent. The subcutaneous adductor tenotomy was done on the right side. The injection pressure was fifty-four millimeters of mercury. A clamp was used, after fixation of the injection substance, to maintain both hips in the same position of internal rotation for the roentgenogram. This position demonstrated the arterial system by throwing its image medial to the femur.
The arterial system of the hip area was more completely visualized on the right side, on which tenotomy had been performed. It was assumed that in the frog-leg position the taut left adductors interfered with the passage of the medium into the hip circulation.

Fig. 7. Case 8, a boy, one day old. The cause of death had been erythroblastosis foetalis.
In the frog-leg position the adductor tendons were very prominent and under marked tension. The adductors were sectioned on the right. The injection pressure was fifty millimeters of mercury.
The arterial tree was well visualized on the tenotomized side. On the non-tenotomized side the femoral circulation was almost completely obliterated.

latter group, the frog-leg position was not used, but one or both extremities were abducted with an extended knee. The findings in these cases partly confirmed the previous results and partly revealed additional information.

Higher injection pressures in infants with poor adductor tone resulted in filling of the arteries in the presence of full abduction of the extremity (Case 11). This was also shown in Case 3.

Abduction with the extremity internally rotated produced poor filling of the arteries in the hip area in the one case in which this was attempted (Case 10).

Again after unilateral tenotomy with the extremities abducted, better filling of the arteries was obtained on the side of the tenotomy (Case 14). If, however, the extremity was forced into further abduction after tenotomy and before the injection, less filling of the arteries was obtained on the side of the tenotomy (Cases 12 and 13). This introduced the question of whether there was diminution of circulation from stretch on the femoral artery or a further compression effect from the non-tenotomized adductor minimus and adductor brevis.

In evaluation of results both postmortem conditions and the physical properties of the injection medium must be taken into account. The nature of muscle rigor differs from the action of muscle tone. The antemortem state of the blood vessels differs from the postmortem state, and the viscosity of blood and the injection medium are dissimilar.

The physical properties of the injection medium are such that it has a definite resistance to flow. Its flow per unit time is relative to the pressure head and is inversely related to vascular resistance. This, coupled with the fact that the mass sets within a relatively

short period of time, enables it to function qualitatively as a pressure or resistance indicator. As it is a varying slurry rather than a uniform suspension, exact quantitation presents an unsolved problem. The absence of injection substance in any area does not necessarily mean that there is a circulatory block, but it may mean that the pressure head in that area is not great enough or that the vascular resistance is too high to permit appreciable flow before setting occurs. This is illustrated by the poor visualization obtained by the low pressure used in Case 2. On the other hand, if the injection pressure is high, no demonstration of the vascular resistance resulting from the frog-leg position can be obtained, as was illustrated in Case 3 (Fig. 2). There are two intermediate states: (1) The pressure is sufficient to visualize the femoral system with the extremity in the neutral position (Cases 4 and 5, Figs. 3 and 4), and (2) the pressure is adequate for filling of both femoral trunks, but is insufficient to fill the arteries in the hip area of the abducted or non-tenotomized hips, as demonstrated in Cases 1, 6, and 7 (Figs. 1, 5-A, 5-B, and 6).

It appears, therefore, that the intravascular resistance or, conversely, the effective intravascular pressure of the hip area is affected by the frog-leg position. The arteries most sensitive to the position are the medial femoral circumflex, the lateral femoral circumflex, and the profunda.

Adductor section apparently abolished the vascular effects produced by the frog-leg position, particularly when adductor resistance had been encountered (Cases 6, 7, and 8, Figs. 5-A, 5-B, 6, and 7.)

SUMMARY

1. There was reason to believe, on the basis of angiography in autopsy material, that the frog-leg position interfered with arterial filling in the hip area.

2. This effect appeared more marked in the presence of adductor resistance.

3. The arteries affected by the position were the medial femoral circumflex, the lateral femoral circumflex, and the profunda femoris.

4. Adductor tenotomy proved to be an aid in abolishing the effect of the frog-leg position upon the arterial circulation to the hip area.

NOTE: Appreciation is expressed in acknowledgment of the cooperation and suggestions of Dr. John W. Hope, Chief of Radiology at the Children's Hospital. Grateful acknowledgment is also made to Dr. Henri Carrier and Dr. Livius L. Lankford, Residents in Orthopaedics.

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DISCUSSION

DR. A. R. SHANDS, WILMINGTON, DELAWARE: The authors' technique of injection is interesting and the results are most informative. The authors state that aseptic necrosis has been seen in normal hips immobilized in the frog-leg position. I have never made this observation. I would question whether adductor resistance in the frog-leg position lasts sufficiently long to do permanent damage to the hip circulation.

The questions which are suggested by this work are: (1) How long does it take for circulatory changes of the character described to affect the nutrition of bone and cartilage? (2) Does the necrotic process take place as rapidly in these tissues as in soft tissues?

It would be worth while to review the congenitally dislocated hips which have been treated during the last twelve and one-half years by closed reduction and immobilization in the frog-leg position in our Hospital in Wilmington. During this period forty hips in twenty-eight patients have had initial immobilization in the frog-leg position after closed reduction for congenital dislocation. Of this number, six hips in six patients, or 15 per cent. of the hips, showed evidence of aseptic necrosis in roentgenograms made five to twenty months

after closed reduction and plaster immobilization in the frog-leg position. In all six hips the functional result was excellent in from two to ten years after reduction. This percentage is much lower than the percentage reported; in our review of the literature, the percentage of aseptic necrosis was found to range from 17 to 59.

Dr. J. Hamilton Allan, Charlottesville, Virginia: Recent end-result studies of congenital dislocation of the hip have suggested that the development of avascular changes in the femoral head after reduction is one of the major factors responsible for an unsatisfactory end result.

Ferguson and Howorth [a], in 1934, described a type of coxa plana which is due to tension of the soft tissues about the femoral neck and which occurs particularly in congenital dislocation of the hip as a result of immobilization in forced abduction and rotation.

Follow-up studies of treatment of congenitally dislocated hips in many clinics have indicated that the incidence of avascular necrosis is much higher in those hips treated by manipulation and immobilization in forced abduction and rotation than in those hips treated by preliminary traction, adductor tenotomy when necessary, and immobilization in less extreme positions.

The anatomical studies of the circulation of the head of the femur by Wolcott [e] and more recently by Tucker [d] and by Howe and his associates [b] have stressed the importance of the medial femoral circumflex artery as the major arterial supply of the femoral head.

Obviously the next step in studying the cause of vascular changes occurring in congenitally dislocated hips after reduction is to demonstrate that the obstruction of this vital blood supply to the hip results from one or more of the various steps in the treatment program.

Dr. Nicholson's method of doing this is most interesting. Although these angiographic studies are subject to many variables, they nevertheless demonstrate that forced abduction and rotation of the extremity combined with increased adductor tension impair the circulation in the hip area. Furthermore, they indicate that surgical release of the adductor tension produced by this extreme position relieves the circulatory disturbance to a considerable degree.

Unfortunately the contrast is not clear enough to pin-point the site of vascular obstruction. Is it, as Tucker has suggested, that the posterior superior and inferior branches of the medial circumflex artery are vulnerable in their course along the femoral neck and are trapped between the femoral neck and the acetabular margin, or is the vascular obstruction close to the point of origin of the medial circumflex, where it can conceivably be compressed by the pectineus, iliopsoas, adductor brevis, and their intermuscular septa?

These angiograms show grossly that the filling defect begins close to the origin of the medial circumflex. It would be enlightening if such a study could be supplemented in one or more of the following ways: (1) by dissection, to visualize directly the results of the injection and the point of obstruction; (2) by a combination of this study with angiographic studies made under similar conditions of stress and adductor tension release but with the use of the Trueta method [c] of injecting the end arteries of the hip; and (3) by demonstrating the point at which vascular obstruction begins in various planes of motion.

Dr. Nicholson's studies have added to our knowledge by demonstrating the importance of eliminating adductor tension as a means of improving our end results in the treatment of congenital dislocation of the hip.

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TORSION OF THE LOWER EXTREMITIES IN SMALL CHILDREN *

BY J. H. KITE, M.D., ATLANTA, GEORGIA

Torsion of the lower extremities in small children usually takes one of two patterns. The children may have medial torsion and be bow-legged and pigeon-toed, or they may have lateral torsion and be slightly knock-kneed and flat-footed.

Medial torsion should be considered in two groups — congenital and acquired — because of differences in etiology and in treatment.

CONGENITAL MEDIAL TORSION

In this group the torsion is chiefly between the knee and the ankle, and there is a marked lateral convexity to the leg (Fig. 1-A). The deformity is present at birth but may not be recognized then.

Etiology

The deformity has been described by Nachlas, who says that it may be either an atavistic reversion or a developmental arrest. The orangutang, the gorilla, and prehistoric man show medial torsion of the leg. The human foetus shows an inward torsion of the tibia during its development. The developmental-arrest theory is more acceptable to the parents.

Signs and Symptoms

The chief complaint given by the mother is that the child is pigeon-toed or bow-

FIG. 1-A

FIG. 1-B

FIG. 1-C

Fig. 1-A: A fifteen-month-old girl, who was breast-fed and given oleum percomorphum for the first eight months. She walked at fourteen months and was bow-legged and pigeon-toed without any signs of rickets. Braces were worn for five months.

Fig. 1-B: The result two years later.

Fig. 1-C: Photograph taken five years after Fig. 1-A.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 30, 1953.

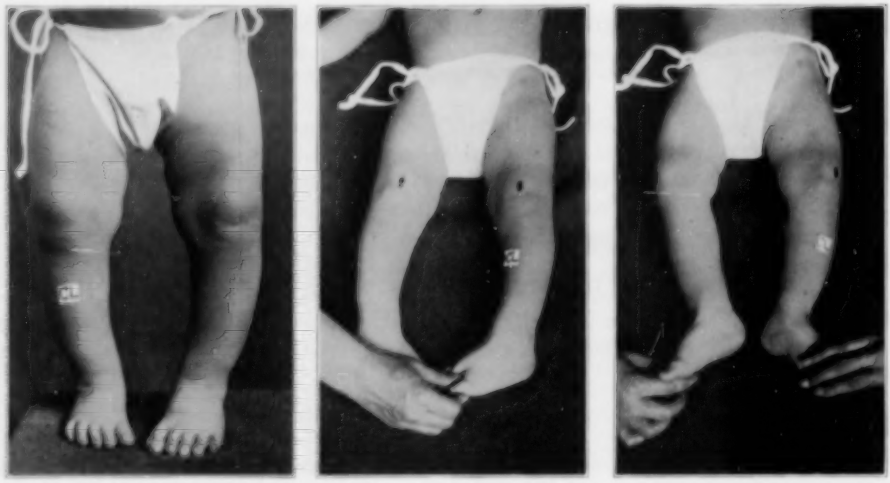

FIG. 2-A FIG. 2-B FIG. 2-C

Rotation test in congenital medial torsion.

Fig. 2-A: In congenital medial torsion, the twisting is chiefly between the knee and ankle. There is also a lateral convexity of the leg.

Fig. 2-B: When the limbs are rotated medially, the patellae can be turned inward as far as they can in normal limbs. In acquired torsion, the patellae can be rotated medially 90 degrees or more.

Fig. 2-C: The limbs can be rotated laterally approximately the normal amount.

legged. The child with this complaint is usually seen between the sixth and the eighteenth month. Sometimes the mother will notice the deformity before she leaves the hospital, or the grandmother will notice it as soon as the baby is brought home. The pediatrician may call attention to the extremities on the first visit. When the medial torsion is noticed shortly after birth, there is no doubt about its being congenital. However, it may be overlooked until the child begins to walk. Then it is more difficult to tell whether the patient has a congenital or an acquired malformation.

The deformity is symmetrical. It occurs in well nourished and, often, in overweight children. When the child stands or walks, the feet are so adducted that at a distance they may suggest metatarsus varus. When he sits with his knees flexed, the feet are adducted and the toes are pointed inward at a 35-degree to 45-degree angle. When he is lying on his back with the limbs extended and the patellae pointing forward, the medial torsion makes the feet point in. In this position, the knees and ankles are about the same distance apart. The child may appear to be slightly knock-kneed. When the limbs are allowed to roll laterally from the hips, the patellae have to point laterally 45 degrees or more to allow the toes to point straight forward. In this position, the limbs appear to be bow-legged. In the average case, when the malleoli are made to touch each other, the condyles of the femora are about two finger-breadths apart and the space below the knees is about three finger-breadths wide. There is very little deformity of the femora in those with congenital medial torsion.

Rotation Test

When the ankles are grasped and the limbs are rotated medially and laterally, the patellae can be turned medially and laterally about as far as in a normal child (Figs. 2-A to 2-C). This is not true in an acquired deformity.

Roentgenograms

In the roentgenograms the shadow of the soft part shows a lateral convexity to the lower leg, but the shafts of the tibia and the fibula are straight (Fig. 3-A). The metaphyses

FIG. 3-A

FIG. 3-B

Fig. 3-A: The shafts of the tibia and fibula are straight, but there is a lateral curving of the shadows of the soft parts. The angulation takes place in the epiphyseal lines.

Fig. 3-B: Normal contour of the bones two years later. The deformity was corrected by double bow-leg braces.

at the distal ends of the femora and the proximal ends of the tibiae show an expansion of the bone on the medial side. The metaphyses extend much further medially than do the epiphyses.

The roentgenograms never show any cupping or fraying suggestive of rickets. There is an increased density of the metaphysis adjacent to the epiphyseal line. In some cases this may be slight, while in others it is marked.

The angulation which produces the lateral convexity takes place at the epiphyseal lines. The change is most marked at the distal epiphysis of the tibia. Instead of the line being perpendicular to the long axis of the bone, it is oblique, facing medially. The tibia is shorter than normal and the fibula is longer.

Nachlas says that the medial torsion can be diagnosed roentgenographically by the fact that one end or the other of the fibula is shown to be twisted behind the tibia. This has been a rare finding in our cases. Most of the children have had roentgenograms made in two positions, one with the patellae pointing forward and another with the toes pointing forward.

Diagnosis

Cases of congenital medial torsion with bow-leg have been misdiagnosed for years as rickets. In these cases of medial torsion, the abdomen is no more prominent, the lumbar lordosis is no more marked, and the Harrison's groove is no deeper than in normal children.

If the very rare cases of "vitamin-D-resistant rickets" are excluded, there is very little evidence in the cases studied that rickets played any part in the production of these cases of bow-leg or knock-knee.

Congenital medial torsion may be confused with congenital metatarsus varus, but the

FIG. 4

FIG. 5

FIG. 6

Fig. 4: The medial torsion is corrected by twisting the limb against the deformity. The mother grasps the medial side of the foot with one hand and the lateral side of the knee with the other and rotates the foot laterally.

Fig. 5: To correct the lateral convexity, the mother stands to the side of the child, grasps the knee with one hand and the ankle with the other, and puts pressure on the lateral side of the leg with the thumbs.

Fig. 6: The brace recommended is attached to a pelvic band. The limbs are set in slight lateral rotation, and there is a little more lateral rotation between the knees and ankles. This corrects the medial torsion. The lateral convexity is corrected by pressure at three points. There is a pad on the medial side of the knee and a strap around the medial malleolus and lateral bar. This fixes each end of the leg. Pressure is put on the lateral side of the leg by a strap around the middle of the leg, which is attached to the medial bar. (This strap is not attached to the lateral bar.)

deformity in metatarsus varus is limited to the foot. In metatarsus varus there is not only adduction of the fore part of the foot and a higher arch, but there is a prominence on the lateral side of the foot near the base of the fifth metatarsal. Muscle imbalance is present. The foot is always supinated and adducted. The foot is less flexible than the normal, and the fore part of the foot cannot be passively abducted past the mid-line.

Other conditions which may cause bowing are quite familiar. Trauma or osteomyelitis may injure the epiphyseal line on one side, stop its growth, and produce an angulation. Chondrodystrophy, osteogenesis imperfecta, and osteochondrosis deformans tibiae (Blount-Barber disease) are so entirely different from congenital medial torsion that they present no problem of differential diagnosis.

Prognosis

There may be spontaneous improvement. This is usually slight and we cannot, with any assurance, say that the child will outgrow the deformity. Without treatment, the prognosis for the children with the congenital type is poor, but for those with the acquired type it is good.

Treatment

The orthopaedist and the pediatrician have, in times past, recommended an increase in the cod-liver oil or "drops", or the change to another cod-liver-oil substitute. Sometimes there was a spontaneous improvement, and the change in oils was given credit. In many cases there was no improvement.

When the child is first seen, it is explained to the mother that this is a congenital deformity, that it is more difficult to correct than the acquired deformity, that the child may need double braces, but that for the first two months conservative treatment should be tried.

Figs. 7-A and 7-B: In acquired medial torsion of the lower extremities, there is a definite medial twist between the knee and the ankle, but the lateral convexity is less than in the congenital type. The position of the feet more nearly resembles congenital metatarsus varus.

Fig. 7-C: The baby sleeps in the knee-chest position with the feet turned medially.

Fig. 7-D: His "position of comfort" is sitting on his feet. If his feet are placed in front of him, he will immediately change his position and sit on his feet.

FIG. 7-A

FIG. 7-B

FIG. 7-C

FIG. 7-D

The mother is shown how to "stretch" the baby's limbs (Fig. 4). While the baby lies on his back, the mother stands facing his feet and grasps the medial side of the foot with one hand and the lateral side of the knee with the other. She holds the knee pointing forward and twists the foot laterally, as in wringing clothes. She holds that position for a full half minute, releases the leg for an instant to rest the baby, and then repeats the exercise. She is instructed to spend about three minutes on each leg twice a day.

The second manoeuvre is to correct the lateral convexity (Fig. 5). The mother stands to the side of the child, grasps the knee with one hand and the ankle with the other, and puts pressure on the lateral side of the leg with the thumbs. The thumbs are placed near the middle of the fibula, and the ankle and knee are drawn laterally, as one would do in straightening a bent wire. She holds this for a half minute, releases the leg for a few seconds, and repeats the exercise. It is suggested that she carry out these two exercises for ten to fifteen minutes morning and night.

If there is no improvement after six to eight weeks, a metal bar may be placed across the shoes to rotate the feet and limbs laterally. It may be worn only at night if the child is walking. This bar simply rotates the limbs outward at the hips, and has little effect on correcting the torsion between the knee and the ankle. The bar does more good in the acquired deformity than in the congenital.

If there is still no improvement, a double brace is applied (Fig. 6). The brace recommended has bars on each side of the limb, with the lateral bars attached to a pelvic band. There are freely moving joints at the hips, knees, and ankles. The lateral bars are so set on the pelvic band as to rotate the feet laterally. There is also a slight twist in the bars between the knees and ankles to turn the feet laterally even a little more. A pad is placed on the bar at the medial side of the knee, and a strap is placed around the medial malleolus and the lateral bar, thus fixing each end of the leg. There is another strap, around the

FIG. 8-A

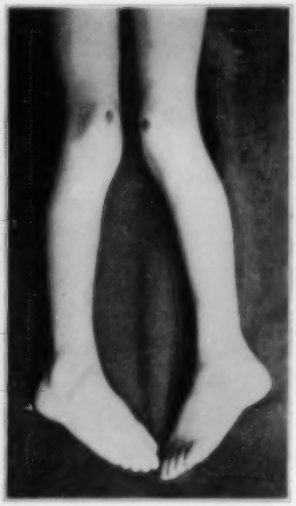

FIG. 8-B

FIG. 8-C

Fig. 8-A: A six-year-old boy who continued to walk pigeon-toed. The patellae could not be turned laterally much past the mid-position.

Fig. 8-B: The patellae could be rotated medially much further than normal, and further than shown.
Fig. 8-C: He sat by the hour in this position watching television.

mid-portion of the leg, which is attached by buckles to the medial bar; this pulls on the lateral side of the leg and corrects the lateral convexity.

The deformity is usually corrected in three to nine months, depending on its severity and the age of the child. When correction has been obtained, the braces are gradually discarded. The child should be observed frequently at this stage, and the braces should be re-applied if he begins to "toe in".

ACQUIRED MEDIAL TORSION

In acquired medial torsion, the limbs are straight at birth, but a deformity is produced by the positions in which the child sleeps and sits[1, 2, 3] (Figs. 7-C and 7-D).

Etiology

The babies with this type of torsion usually sleep on the stomach, in a knee-chest position with the toes turned inward. For the very young infant, this is the "position of comfort", since it was probably its foetal position. The baby will often drop off to sleep when placed in the knee-chest position. Some pediatricians have recommended this position as a means of expelling gas. The mothers like it because the baby cannot kick off the covers. However, more mature thought will show that this is a very bad position for the lower extremities. With the fifth toe resting on the mattress, the fore part of the foot is adducted on the posterior portion, causing the foot to be in the position of congenital metatarsus varus deformity. The foot is twisted medially at the ankle and the limb is twisted medially at the knee. The knee and hip are held in a fully flexed position for hours. The convexity of the buttock fits into the concavity of the foot. The weight of the body pressing down on the legs will alter the shape of the bones. This pressure will also cause a relaxation of the ligaments at the knees and ankles. This position may be used until the child is old enough to turn over by himself, and in some cases the child may sleep in this position until he is several years old.

The child who finds the knee-chest position the position of comfort will also "sit on his feet",—that is, with the knees flexed and the feet turned inward behind him. The skin will often be thickened on the lateral side of the foot over the head of the talus and

over the anterior lateral corner of the calcaneus from the constant pressure of sitting on the foot.

Signs and Symptoms

The child is bow-legged and pigeon-toed. The findings are similar to those described for congenital medial torsion, but are usually less pronounced. The history of the sleeping and sitting habits will help in making the diagnosis.

Roentgenograms

The roentgenographic findings are similar to those in the congenital group. There is no definite finding by which we may separate the two groups. In some cases it seemed that the increased density of the metaphysis was a little more marked in the acquired group. According to Wolff's law, this change of the internal structure of the bone may be produced by the external stresses and the strain placed on the epiphyseal lines by the bow-leg deformity.

Diagnosis

The deformity of acquired medial torsion is usually less marked than that of congenital medial torsion, and it is usually not noticed until the child begins to sit and crawl. The best differential sign is the test of the range of rotation of the limbs.

Rotation Test

In the congenital torsion the patellae can be turned medially and laterally about as far as in the normal child. In the acquired torsion the patellae can be turned medially 90 degrees or more, but they cannot be rolled laterally much past the mid-position (Figs. 8-A and 8-B).

Another test is to observe the child as he sits and plays. He will usually sit on his legs with his toes

FIG. 9-A

FIG. 9-B

FIG. 9-C

FIG. 9-D

Fig. 9-A: Lateral torsion of the lower extremities. The child is flat-footed and slightly knock-kneed. The limbs roll out from the hips. The patellae point laterally.

Fig. 9-B: When he sleeps in the prone position, the great toe rests on the mattress and the metatarsus is pushed laterally into a flat-foot position.

Fig. 9-C: Rotation tests show that the limbs cannot be rotated medially past the mid-line.

Fig. 9-D: The patellae can be rotated laterally 90 degrees or more.

FIG. 10-A

FIG. 10-B

Fig. 10-A: Lateral rotation and flat feet.

Fig. 10-B: This sitting position forces the feet into a flat-foot position.

turned in. If he is moved and made to sit "tailor fashion", in a few seconds he will change and sit on his feet again, because this is his position of comfort.

Prognosis

The prognosis is much better in this type of deformity. These are the limbs which straighten with little or no treatment.

Treatment

The first thing to do is to correct the faulty sleeping and sitting habits. If this idea is as important as it seems at present to be, the orthopaedist should pass it on to the pediatricians in his community and to the mothers of his own patients, in order to prevent deformity in future babies. A blanket can be rolled up and placed as a pillow behind the baby's shoulder and hip to help him to lie on his side. The mother should place him on one side for one sleeping period, and on the other for the next. It is not safe to place the infant on his back when his stomach is full. When awake, he may be placed on his stomach, with his lower extremities extended, for exercise and play.

When the bow-legged and pigeon-toed deformity has been acquired, it can often be easily corrected by the manipulations described for treatment of the congenital deformity. Frequently, the bar across the shoes is all that is needed; double braces will not be necessary. The bar will be enough to keep the child from sleeping with the feet turned in and will hold the limbs in lateral rotation. The child should sit on a small chair which is low enough to permit his feet to touch the floor, or he should be taught to sit tailor fashion on the floor.

The feet are often flat and have flat-foot imprints even though there is adduction of the fore part of the foot. The heels may be in valgus. Instead of using the swing-in shoes which are used for flat feet, it is better to use a normal shoe with a straight last and have a wedge, one-eighth of an inch thick, inserted in the medial border of the heel.

LATERAL TORSION

Lateral torsion is the reverse of the medial torsion. In addition to the lateral rotation of the lower extremities, there is some knock-knee deformity and usually a severe flat-foot deformity (Figs. 9-A to 9-D).

Etiology

The group of patients to be discussed here are also babies who acquire the deformity from faulty sleeping and sitting habits. These babies sleep on either the abdomen or the back with the lower extremities in a "frog" or "spread-eagle" position. A few may sleep in the knee-chest position with the toes turned out in a flat-foot position.

The foetus has been floating in amniotic fluid with the limbs flexed. After birth, the baby is placed on a firm mattress with stiff new diapers which are too large and which are tightly pinned. These hold the thighs out at right angles to the body in a frog-like position. The knees are flexed at right angles, which rotates the thigh laterally 90 degrees. The same is true when the baby is placed on his back. These babies are seldom placed on their sides.

FIG. 11-A

FIG. 11-B

FIG. 11-C

Unilateral torsion.

Fig. 11-A: When only one limb is curved, the deformity is usually an acquired one. It may be severe, such as the one shown here.

Fig. 11-B: The child crawls with the foot turned in.

Fig. 11-C: He always sits on this foot, increasing the deformity.

When they are old enough to sit, they usually sit with their legs crossed in front of them in tailor fashion. Others will sit with the knees flexed and the feet behind them and lateral to the hips and with the toes turned laterally (Fig. 10-B).

Signs and Symptoms

The chief complaint in this group is that the feet turn out, or that they are flat. The parents seldom notice that the knees are rotated laterally about the same amount as the feet, and that the limbs roll out from the hips. It is sometimes said, "One foot goes east and one foot goes west".

The flat-foot deformity is produced by this position of lateral rotation. When the baby is prone in the frog position, the medial border of the great toe rests on the mattress, and the metatarsus is forced into abduction. This bends the foot in the middle. It also twists the ankle laterally and everts the heel. Later, when the baby is placed on his back, his limbs assume the same position. The heel rests on the mattress, and the weight of the fore part of the foot again bends the foot out in abduction, making it a flat foot. The tibial muscles are stretched and work from "around the corner", at a mechanical disadvantage. The peronei are in a shortened position, pull more nearly in a straight line, and work at a mechanical advantage. The foot is pulled out and up in a calcaneovalgus position. The longitudinal arch is obliterated. The foot bulges inward along the medial border, and a severe flat foot is produced. There may be some knock-knee deformity, although this is not so important as the outward rotation of the entire limb from the hip.

Rotation Test

In attempting to rotate these limbs medially, we find that they can be turned inward until the patellae point straight forward, but they cannot be turned in much further. They can be rotated laterally at least 90 degrees or more. It is usually impossible to fold these limbs back under the child so that he can sit on them. If it can be done, the child will stay in that position only a few seconds and he will then straighten his limbs and sit tailor fashion again.

Diagnosis

Little difficulty is experienced in distinguishing this condition from congenital flat feet, which are recognized at birth. The congenital flat feet are pulled up in a calcaneo-valgus position from birth, and with slight pressure the dorsum of the foot can be made to touch the lateral border of the leg. Lateral torsion of the limbs is seen in poliomyelitis, spastic paralysis, and in malunion following a fracture, but these offer no difficulty in diagnosis.

Treatment

Treatment consists in breaking the faulty sleeping and sitting habits. When the infant is placed so that he lies first on one side and then on the other, the lower extremities are both rolled into a neutral position. The anterior surface of the thighs and the anterior surface of the abdomen are in the same plane. When the baby sits, he should sit in a small chair, which will flex the knees and put the femora in a normal mid-position.

The parents are taught to grasp the knees and to rotate the limbs medially as far as possible and to hold them this way for a half minute at a time, trying to undo what gravity has done in rolling the legs laterally. This should be done for at least five minutes in the morning and five minutes at night. The parents are also shown how to hold the feet to turn the fore part of the foot downward and inward to correct the flat-foot deformity[4, 5, 6]. When the patient is old enough to walk, he should wear swung-in shoes. If this does not correct the deformity in a few months, the child should wear a splint at night. This consists of swung-in shoes attached to a bar, with the shoes turned in on the bar, and the bar bent toward the body in order to tilt the heels into a varus position and to correct the flat-foot deformity even more.

UNILATERAL TORSION

Occasionally we see a child with only one limb turned in or out and the other straight (Fig. 11-A). This is usually an acquired deformity. It is produced by the child sitting and sliding with one foot under him and the other stretched out in front of him. This can usually be remedied by correcting the sitting habits and by manipulations. Occasionally a long brace is applied to the crooked limb to correct the deformity.

These are the more common deformities encountered. There are many possible combinations which can be explained by a study of the sleeping and sitting habits of the child. More than 800 cases of torsion of the lower extremities have been studied at the author's office and at the Scottish Rite Hospital for Crippled Children.

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DEVELOPMENTAL DEFORMITIES OF THE LOWER EXTREMITIES *

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The importance of certain sitting and sleeping habits of the infant and child deserve emphasis; these habits may interrupt the normal developmental pattern of the lower extremities and even cause deformities. Their importance is not recognized by the profession as a whole. Orthopaedic surgeons should impart preventive information about them to pediatricians, obstetricians, nurses, and parents.

Twenty years ago, Dr. Nachlas read a paper before this Association on "Medial Torsion of the Leg" in which he stressed the fact that many children who were presented for treatment because of bow-leg or pigeon-toe had a medial tibial torsion. This has been considered to be an atavistic reversion or a developmental arrest.

Fitzhugh was one of the first to call attention to the relationship of sleeping, sitting, and play postures to developmental deformities.

Lowman, Lewin, Hutter and Scott, Badgley and O'Connor, and others have written on this subject. Howorth's work gives the most adequate discussion of the problem of any orthopaedic text; others fail to mention torsion or rotation and still list rickets as the fundamental cause of knock-knee and bow-leg.

Chapple has shown that intra-uterine position may be an etiological factor in deformity of the newborn; it is a logical corollary that sleeping and sitting habits might well influence the maintenance of certain of these postures, as well as increase their severity.

With the virtual elimination of rickets, bow-leg and knock-knee deformities in severe degree are rarely seen now, but they are frequently encountered in mild or moderate form. They are usually accompanied by a medial tibial torsion (in the case of bow-leg) or by a lateral rotational deformity in the knee (in the case of the knock-knee). The usual explanation of rachitic softening as the cause of these diverse deformities is inadequate. Why should rickets alone cause both knock-knee and bow-leg? What factor makes one child knock-kneed and another bow-legged? Not infrequently, correction of the torsional or rotational deformity will satisfactorily correct the deformity in the lateral plane as well. On the other hand, correction of the lateral deformity without correction of the rotational element will leave the child with an awkward gait, resulting from either pigeon-toe or "slew-foot", and with varus or valgus position of the feet.

Most newborn infants have a medial tibial torsion varying from 5 to 30 degrees, a mild bow-leg deformity involving both the tibia and the femur, and knee-flexion and hip-flexion attitudes. Whether these conditions are truly atavistic or are due to the intra-uterine position is not settled; Chapple is of the opinion that intra-uterine positional factors are of great importance. In the course of normal development, these attitudes undergo spontaneous correction as long as extraneous factors do not interfere. Most mild lateral deformities will correct with time and growth, but the rotational deformities are not so apt to correct spontaneously. The normal "pendulum swing" from bow-leg to knock-knee and back again, with final spontaneous correction, was first described by Böhm in 1933, and was later emphasized by Blount and White. This does not always take place, and there is no certain method of predicting which child's extremities will correct spontaneously and which child's will not. Whitman, in a survey, found 400 cases of bow-leg and thirty-two cases of knock-knee among 2,000 adult males. He concluded that natural

* Read at the Annual Meeting of The American Orthopaedic Association at Hot Springs, Virginia, June 30, 1953.

forces are often ineffective in completing the cure. Therefore, we should lend assistance to patients who are likely to appreciate the advantages of symmetry over deformity, even though the deformity is not attended by discomfort or disability. Until we can accurately differentiate physiological from pathological deformities, all of those children who present excessive rotational deformities or lateral deformities which are cosmetically unacceptable should be treated.

FIG. 1

FIG. 2

FIG. 3

Fig. 1: Mother carrying child astride hip.

Fig. 2: Reverse tailor sitting position with the feet beneath the buttocks is productive of medial tibial torsion.

Fig. 3: Tailor sitting position.

Sleeping in the prone knee-chest position is encouraged by the majority of physicians and parents. By the time the child is able to turn in the crib, this habit of sleeping in a prone position is firmly fixed and ordinarily persists for four to six months; in some instances, it may continue into the third or fourth year. During early life, the long hours of sleep that are the rule may favor twists and

FIG. 4

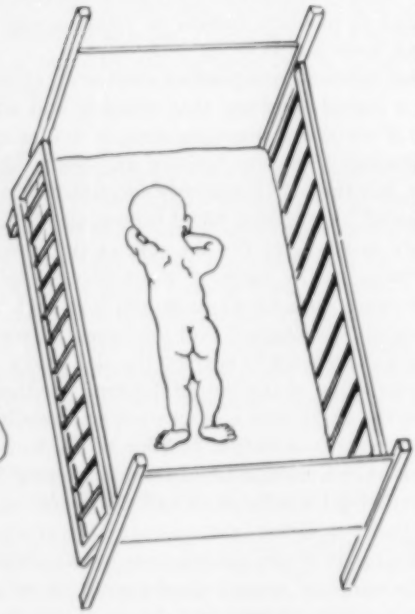

FIG. 5

FIG. 6

Fig. 4: Prone "frog-leg" sleeping position with the feet everted predisposes toward external rotational deformities of knees and valgus position of feet.

Fig. 5: Prone sleeping position with the feet everted and limbs externally rotated.

Fig. 6: Reverse tailor sitting position with the feet externally rotated.

bowings which would not otherwise persist or develop were the child to turn at frequent intervals and not maintain the same posture for long periods.

The infant should be placed on alternate sides for sleeping, and on the back or stomach during his waking hours. From the first, he should be watched to see that no position

is maintained for too long and that vicious postures are not allowed to develop. The advantages cited for the prone position are said to be (1) that the baby "burps" more easily, (2) that he does not kick the covers off as easily, (3) that flattening of the back of the head and wearing off the hair are avoided, and (4) that he can lift himself on his hands and arms, thereby strengthening his muscles and giving him better command of himself. However, these advantages do not outweigh the dangers of the prone position for the inactive hours of sleep. Sleeping on the back is objectionable because the spread-eagle or "frog-leg" position, further encouraged by the pressure of the diaper, is conducive to the development or the aggravation of rotational deformities. Such a sleeping posture is frequently found in the fat sluggish baby with external rotation attitudes of the hips, valgus position of the feet, and, on walking, marked out-toeing or slew-foot. If the infant is taught from the beginning to sleep lying on his side, no difficulties are encountered.

The diaper may also be a deforming factor. All too often, an infant is seen wearing a double-thickness, tightly pinned diaper and a plastic diaper-cover—in effect, a poor Frejka splint! Such a diaper encourages hip-flexion and knee-flexion attitudes, as well as the prone sleeping position and bowing of the legs. Bulky diapers, worn twenty-four hours a day during the first months of a baby's life, obviously must have a deforming effect. Hygienically they may be good, but orthopaedically they are less than satisfactory.

Charts I and II show the results of a study of foot alignment in relation to sleeping position as reported by Thelander and Fitzhugh. The study included 246 children from six months to five years of age, the majority being between eighteen and thirty-six months of age. In these charts, *Neutral* indicates a variance of 10 degrees or less, either way, from a true mid-position of hip, knee, and foot. *Deviation* indicates 10 degrees to 90 degrees of in-toeing or out-toeing.

In the first two or three years of life, many children are carried astride the mother's hip, the child clinging to her with his legs while he is held about the waist. Such a posture, maintained for long hours, encourages the development of bow-leg, and even of medial tibial torsion and varus deformity of the fore part of the foot (Fig. 1).

Later in infancy, the waking habits will tend to follow the sleeping position, especially in the case of the knee-chest sleeper. The earliest sitting posture of this baby is often the tailor position in reverse. He will sit between his flexed extremities with the feet either inverted beneath his buttocks (Fig. 2) or everted. This broadens and stabilizes his sitting base in addition to being similar to his sleeping habit. Formerly, persistence of this habit was most frequent in girls while playing with dolls or jackstones; now television has become a major instigating factor in its persistence in both boys and girls. Frequently, callouses develop over the peroneal tuberosity of the calcaneus and over the head of the talus as a result of prolonged sitting on the inverted foot. Now we call them "television bumps". The shoes may also show signs of extra wear on the lateral aspect of the uppers—further evidence of this positional habit. The most satisfactory sitting posture for this child is the cross-legged tailor position (Fig. 3).

In the search for the causes of these twists and lateral deformities, the play apparatus must not be overlooked. The "walker" is a common offender, since it is propelled by the push-off of the everted feet while the knees are flexed and abducted. Canvas swings and jumpers produce the hip flexion-abduction position, encouraged by the bulky diaper.

The following outline shows the deformities which are associated with certain habitual sleeping or sitting positions. The prone knee-chest sleeping posture, seen most frequently, is the most commonly offending sleeping position.

SLEEPING HABITS

I. Prone knee-chest position with:
   a. Extremities internally rotated, results in:
      (1) internal rotation deformity of the hips,

(2) medial tibial torsion,
(3) bow-leg,
(4) ankle equinus,
(5) adduction and varus of the fore part of the foot (may appear to be a mild metatarsus varus).

b. Extremities externally rotated, results in:
(1) external rotational deformity in the knees,
(2) knock-knee,
(3) ankle equinus,
(4) valgus of the feet.

c. Extremities neutral, results in:
(1) ankle equinus (toe-walking of early childhood).

II. Frog-leg position, most frequently prone (Fig. 4) but occasionally supine, results in:
(1) external rotation deformity of the hips,
(2) external rotation deformity in the knee joints, in conjunction with shortening of the iliotibial band and of the biceps femoris,
(3) knock-knee,
(4) valgus and abduction of the feet.

III. Prone, with hips extended and:
a. Internally rotated, may result in:
(1) internal rotation contracture of the hips,
(2) medial tibial torsion (to a lesser degree than that which results from the knee-chest position),
(3) ankle equinus,
(4) varus of the metatarsus, with or without adduction.

b. Externally rotated (Fig. 5), may result in:
(1) external rotation contracture of the hips,
(2) external rotation deformity in the knee joints,
(3) ankle equinus,
(4) valgus of the feet.

SITTING HABITS

I. Reversed tailor position with:
a. Feet internally rotated beneath the buttocks (sitting on the feet), results in:
(1) internal rotation contracture of the hips,
(2) medial tibial torsion,
(3) adduction of the fore part of the foot.

b. Feet externally rotated * (Fig. 6), results in:
(1) internal rotation contracture of the hips,
(2) external rotation deformity in the knees,
(3) knock-knee, with relaxation or stretching of medial collateral ligaments,
(4) valgus deformity of the feet.

c. One foot internally rotated and the other externally rotated.

DISCUSSION

When the child is first brought for examination, a complete physical survey is made, including routine roentgenograms of the hips and lower extremities. Tibia vara, dyschondroplasia, and nutritional disturbances are ruled out. A neurological examination is made, since these postural defects are also frequently associated with a mild cerebral palsy, particularly an ataxia or a mild spastic paraplegia of prematurity.

* Many children with mild cerebral palsy, particularly those with ataxia, will sit in this position because of the broader base and the greater stability which it affords.

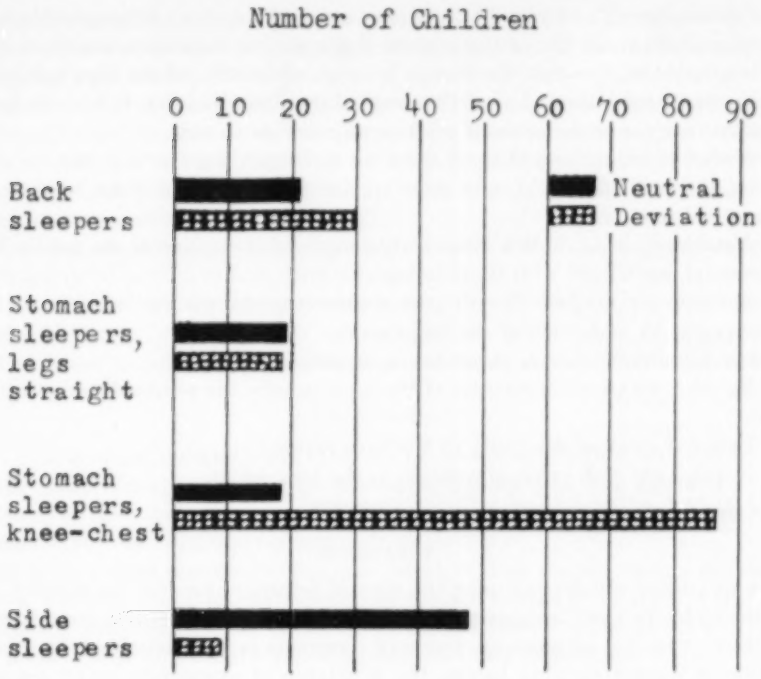

CHART I

(Chart I is reproduced by permission of Mrs. Mabel Fitzhugh and the *Physical Therapy Review*[6], as well as of Dr. H. E. Thelander and *The Journal of Pediatrics*[12].)

From a practical standpoint, the most common causes of in-toeing or pigeon-toe are:

1. *Internal rotation contracture of the hips:* Children with this deformity are free of torsion and foot deformity, but they have a range of internal rotation of the hips of 75

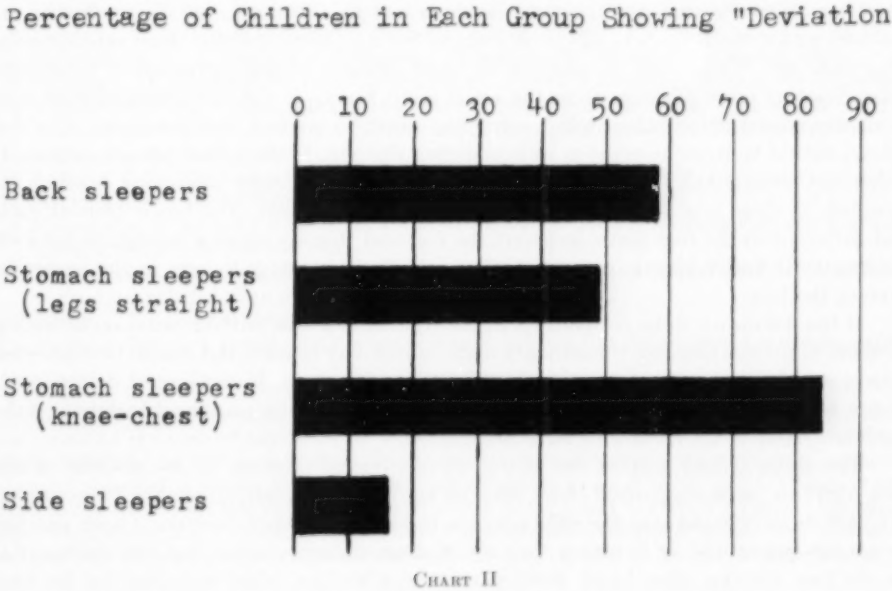
Percentage of Children in Each Group Showing "Deviation"
0 10 20 30 40 50 60 70 80 90
Back sleepers
Stomach sleepers (legs straight)
Stomach sleepers (knee-chest)
Side sleepers

CHART II

to 90 or more degrees and very little, if any, external rotation. Although this is the so-called congenital anteversion of the neck of the femur, we have been unable to prove by roentgenographic studies that the change in range of rotation of the hips is the result of persistent, increased anteversion of the neck of the femur; rather, it is considered that the internal rotators or the anterior joint capsule are shortened.

2. *Medial tibial torsion:* There is often an accompanying bow-leg, but on closer examination, the bowing is found to be more apparent than real and of less relative severity than the tibial torsion.

3. *Metatarsus varus:* This is often truly congenital, but some of the milder cases are developmental, associated with tibial torsion.

4. *Symptomatic flat-foot:* In-toeing is a compensatory attempt to relieve a painful pes planovalgus by adduction of the metatarsus.

The most common causes of out-toeing or slew-foot are:

1. External rotation contracture of the hips, usually the result of a frog-leg sleeping position,
2. External rotation deformity in the knee joints,
3. Knock-knee with external rotation in the knee joints,
4. Flat-foot, either with or without symptoms.

TREATMENT

The treatment will depend upon the type of deformity present, its severity, and the age of the child. In most instances, conservative measures must be instituted before the age of three years if a satisfactory degree of correction is to be obtained. In infants, the institution of correct sleeping habits, the avoidance of excessively bulky diapers, and rotational stretching exercises are ordinarily adequate. If the deformity is severe, and especially if medial tibial torsion is present, the use of Denis Browne splints should be instituted as early as practicable. Later, proper sitting habits should be developed.

Torsional stretching exercises, while theoretically good, have not proved of particular benefit. They are psychologically helpful in some instances, although the busy mother usually does not have time to carry them out faithfully and regularly and will soon stop them.

The Denis Browne night splints, as described by Thomson, are very effective in children under three years of age; it is unusual for a child to tolerate them satisfactorily after that age. This splint, in addition to being efficient in the correction of rotational deformities, is more effective than the usual night braces in the correction of mild and moderate lateral deformities. Splint correction must be gradual and persistent, and the splints should be worn at night as well as during the nap. If the splints are not tolerated, either the parents are at fault, the shoes do not fit, or too rapid correction is being attempted. If there is a bow-leg element, a long crossbar is used. The bar is bent at each end, adjacent to the foot plate, to invert the feet and thereby avoid a secondary flat-foot deformity. If knock-knee is present, a short crossbar is used; it is bent in the center to protect the feet.

If the deformity to be corrected is primarily a lateral one, without rotation or with a minimal rotational element, the ordinary night splints may be used, but should be connected with a crossbar to prevent rotational positions during sleep. If the lateral deformity is severe, leg braces with rigid knee joints and a pelvic band are also employed during the waking hours, so that the corrective force is constant.

The shoes should support the feet in an anatomical position. If the position of the foot warrants, arch-supportive shoes may be used. When a corrective shoe is necessary, the parents are warned that the child may toe in more than when barefoot. Outer patches to correct pigeon-toe or in-toeing may be of some cosmetic value, but are detrimental to the feet. On the other hand, inner patches and wedges, when indicated for flat-foot

and toeing-out, or slew-foot, are beneficial to the feet, as well as cosmetically helpful. Spiral elastic twisters, extending from a belt about the waist to the shoes, are ineffective and encourage knee-flexion attitudes.

Surgical correction is indicated for children six years of age and over if the deformity is cosmetically objectionable. It is better to perform these procedures prior to the child's first year in school or as soon thereafter as it can be arranged, rather than to pursue a "wait-and-see" policy.

The measures ordinarily employed are:

1. Femoral rotational osteotomy for hip-rotational deformity, if there is minimal or no associated tibial torsion or foot deformity;

2. Femoral and tibial alignment osteotomies for severe bow-leg and knock-knee deformities;

3. Combined rotational and alignment osteotomies if both rotational and lateral deformities are present.

CONCLUSIONS

1. Developmental deformities of the lower extremities in children are most frequently the result, either directly or indirectly, of sleeping, sitting, and play habits of infancy.

2. Some of these deviations persist while others may disappear with normal development under favorable conditions of symmetrical activity.

3. It is not always possible to determine which of these malalignments will disappear and which will not. Since we are not safe in assuming that all of them will disappear spontaneously, measures should be taken to correct objectionable twists and bowings already present, and to prevent the development of other deformities.

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DISCUSSION

Dr. M. Beckett Howorth, New York, N. Y.: I have not found such a clear-cut distinction between the congenital and acquired torsions as Dr. Kite has, especially since each factor may influence the other. While today we have had good descriptions of anatomical findings in these infants, we have had no real documentation and no control cases, and we are still completely at sea as to the specific etiology of these intra-uterine deformities. What has been said and written in the past as to etiology is almost pure speculation. When we say that a deformity is atavistic or shows arrested development, are we using mere words, or do we refer to the results of scientific investigation? How much of what we have seen represents variations

(*Continued on page 558*)

THE 45-DEGREE ANGLE ROENTGENOGRAPHIC STUDY OF THE PELVIS IN CONGENITAL DISLOCATION OF THE HIP *

BY CARL D. MARTZ, M.D., AND CLIFFORD C. TAYLOR, M.D., INDIANAPOLIS, INDIANA

From St. Vincent's Hospital, Indianapolis

Accurate visualization of the relationship of the femoral head to the acetabulum is essential for the proper care of congenital dislocation of the hip. Routine roentgenographic studies demonstrate clearly the supero-inferior and mediolateral displacements of the femoral head, but the vital dimension of depth in which anterior and posterior displacements occur is not readily visualized. Lateral views are frequently unsatisfactory because of the superpositioning of other structures. Furthermore stereoscopic views are not practical for active infants.

For these reasons we have utilized an anteroposterior, 45-degree cephalad view. Clear films are possible no matter what position of the limbs is selected. Standard roentgenographic equipment and techniques are used. The anatomical landmarks are those ordinarily used, and the spine of the femoral neck may be used as a landmark in the early months of life before the ossification center of the head appears. Many of the classically described relationships are visualized in this angled view.

The patient is placed flat on his back. The lower extremities should be fairly symmetrically placed, but abduction, flexion, and rotation of the extremities are at the pleasure of the surgeon. The x-ray tube is centered in the mid-line of the body and is directed toward the symphysis pubis. A routine anteroposterior roentgenogram of the pelvis is made, and then a 45-degree cephalad roentgenogram is made with the x-ray tube still centered on the symphysis pubis. The anteroposterior roentgenogram reveals superior or lateral displacement of the femoral head in relation to the acetabulum. The 45-degree cephalad roentgenogram reveals anterior or posterior displacement. When the head is anterior to the acetabulum, its shadow on the angled view is closer to the top of the roentgenogram than the acetabulum; when the head is posterior to the acetabulum, its shadow on the angled view is closer to the bottom of the roentgenogram. This femoral head-to-acetabulum relationship on the 45-degree cephalad roentgenogram is shown in Figure 1. When the head is in the acetabulum (*n*), its shadow is in the cup; when the head is anterior to the acetabulum (*a*), its shadow is above the cup; and when the head is posterior to the acetabulum (*p*), its shadow is below the cup.

The illustrations were selected from anatomical and clinical material. A dry skeleton was placed upon the roentgenographic table in the supine position. The head of the right femur was placed in the acetabulum, and a routine anteroposterior roentgenogram (Fig. 2, *2A*) was made. A well articulated hip joint was visualized. Without change in the position of the skeleton, the x-ray tube was moved toward the foot of the table and was angled cephalad 45 degrees, with the central ray directed toward the symphysis pubis. The film thus exposed (Fig. 2, *2B*) again demonstrated a well articulated joint. The head of the femur was then dislocated directly anterior to the acetabulum, and both a routine anteroposterior roentgenogram (Fig. 2, *1A*) and a 45-degree cephalad roentgenogram (Fig. 2, *1B*) were made. In the routine view, the shadows of the head and acetabulum are on the same level, but in the 45-degree cephalad roentgenogram, the shadow of the head is separated from the shadow of the acetabulum and is near the top of the film. The femoral head was then dislocated directly posterior to the acetabulum, and a routine anteroposterior roentgenogram (Fig. 2, *3A*) and a 45-degree cephalad roentgenogram (Fig. 2, *3B*) were made. In the routine anteroposterior view, the shadows of the head and acetabulum are on the

* Based on an exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1953.

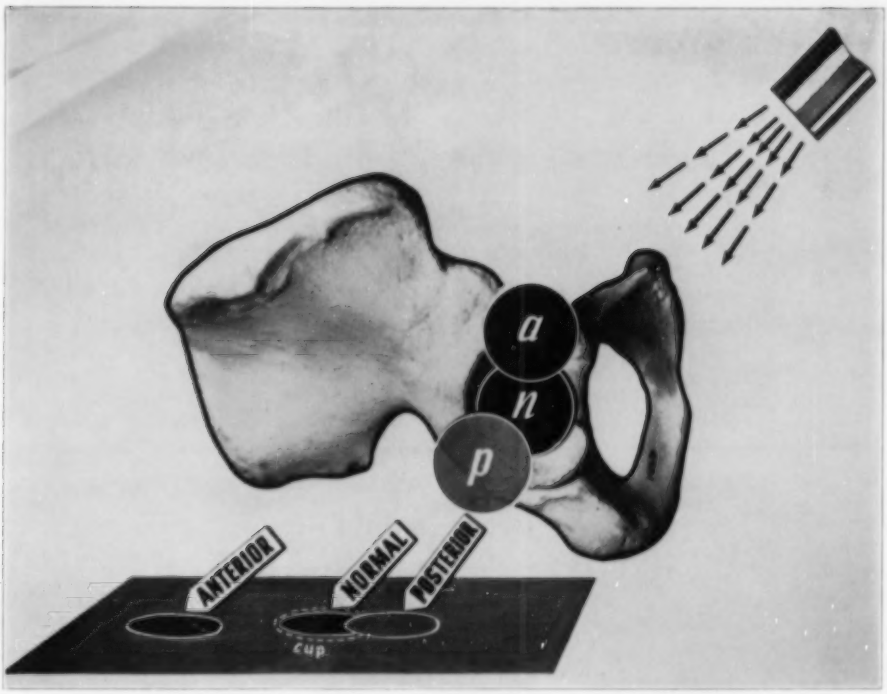

FIG. 1

same level and appear not too different from those in the roentgenogram of the anterior dislocation (Fig. 2, *1A*). However, on the 45-degree cephalad view (Fig. 2, *3B*), the shadow of the head is separated from the shadow of the acetabulum and is toward the bottom of the roentgenogram.

Similar roentgenograms were obtained in living patients. In a normal child (Fig. 3, *2A* and *2B*), the head and the acetabulum maintain their normal relationship. In an anterior displacement of a dysplastic left hip (Fig. 3, *1A* and *1B*), the shadow of the head is separated from the shadow of the acetabulum and is at the top of the film on the 45-degree cephalad view. In a traumatic posterior dislocation of the right hip (Fig. 3, *3A* and *3B*), the shadows of the head and acetabulum are on the same level in the routine anteroposterior view, but on the 45-degree cephalad view, the shadow of the head is separated from the shadow of the acetabulum and is toward the bottom of the roentgenogram.

Clinically, hip dislocations are often complex, involving displacements in superoinferior, mediolateral, and anteroposterior planes. These can be visualized in the routine anteroposterior and the 45-degree cephalad roentgenograms. Anteversion and retroversion of the femoral head and neck are suggested by a study of the various roentgenograms, but accurate measurement of these must await the refinement of the techniques recently proposed by others [2, 3, 4]. The method herein described is designed only to demonstrate the relationship of the head and acetabulum. Anterior and posterior displacements have been demonstrated, and our care of these problems has been given with more assurance than was possible heretofore. We have been able to recognize early those congenital dislocations of the hip which have anterior displacement of the head and have been able to correct this by proper positioning. Furthermore, by the use of this view we could verify the success of our plan of treatment. It is of interest to note that in fifty cases studied over a five-year period, when sagittal displacement occurred in the dysplastic hip, it was almost always anterior. The one traumatic dislocation, which occurred in a young child, proved to be

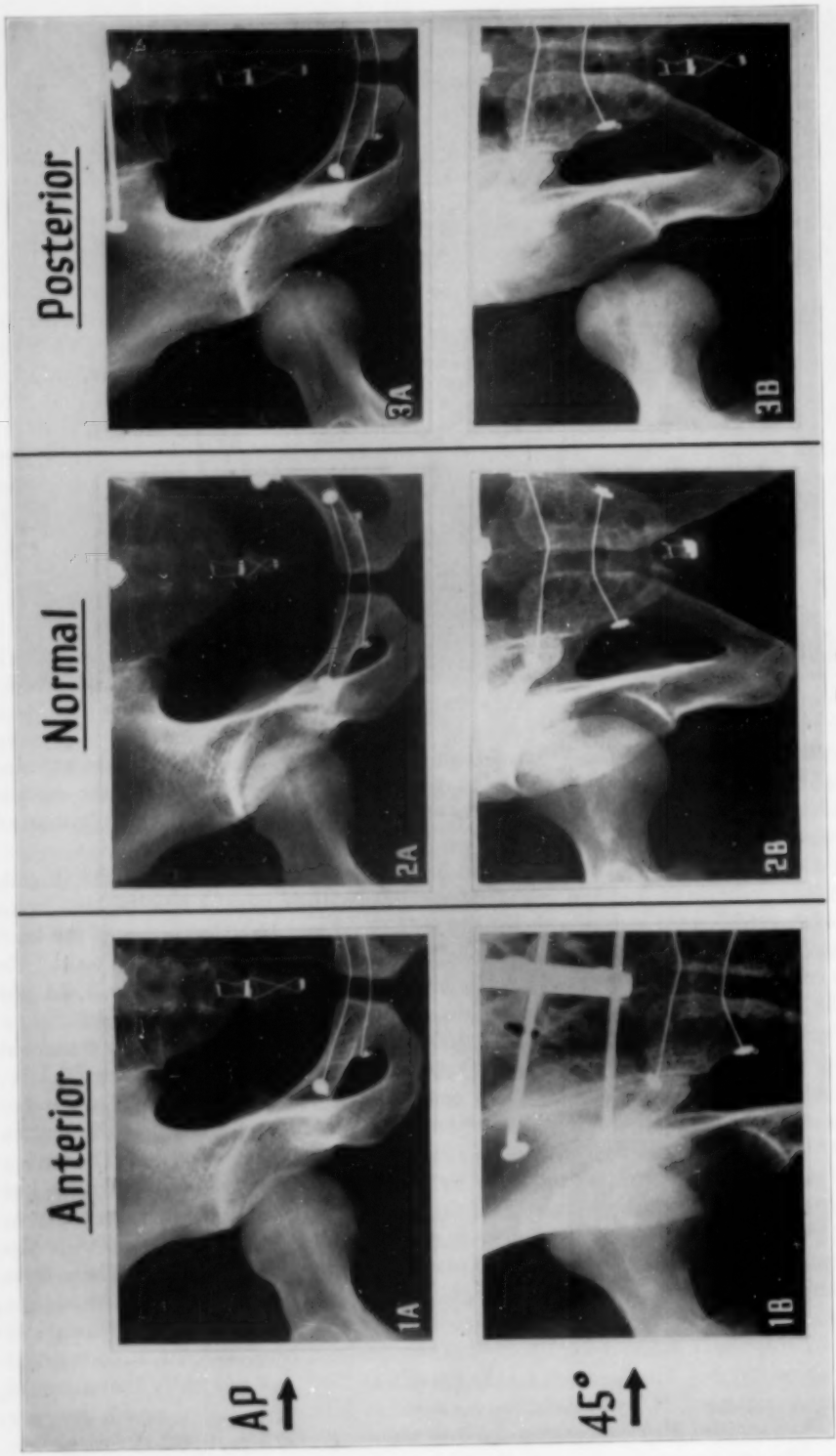

FIG. 2

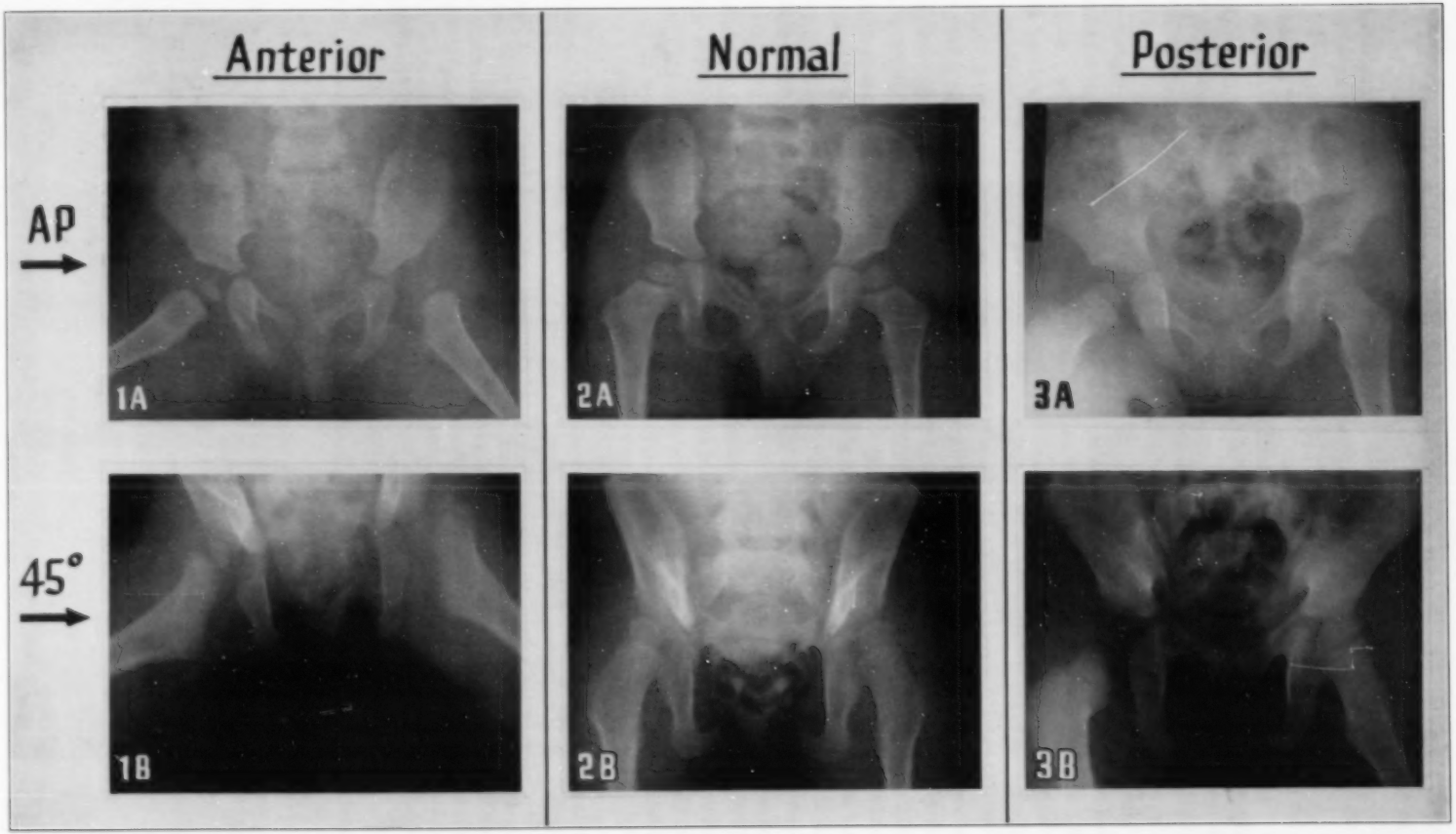

FIG. 3

posterior. Posterior displacement of dysplastic hips in children not yet able to walk was encountered occasionally when hip flexion in the cast was greater than 90 degrees. In these children, the dislocated femoral head had apparently been thrust downward against the imperfect portion of the hemispherical acetabulum in the region of the transverse ligament. Dislocation downward and posteriorly resulted. The "flat-frog" position produced anterior displacement on several occasions. The femoral head was apparently pried forward with resulting anterior dislocation. Such visualization of errors has prompted us to employ positioning of less than 90 degrees of flexion and abduction and to use the position of internal rotation more frequently, as has been long and vigorously recommended by Carl Badgley. In spite of these improvements in technique in both closed and open procedures, we still encounter many failures due to the incongruity of the head and acetabulum. The surgical formation of a shelf is of little value unless and until the dynamic thrust of the femoral head is directed along the central axis of the hemispherical acetabulum which faces forward, outward, and downward. If this proper relationship can be restored early enough, satisfactory end results will occur without surgery, as the result of the stimulation of normal forces. If such positioning is delayed, however, irreparable maldevelopment and disproportion of the femoral head and acetabulum ensue. The coxae magnae which occur in dysplasia are perhaps more to be feared than the occasionally encountered diminutive heads of true congenital dislocations, for the incongruity of the dysplastic head and acetabulum leads almost invariably to disabling arthritic changes, whereas a primarily dislocated head may do well if replaced in an acceptable acetabulum. Neither incongruity of the head and acetabulum nor the coincident distortion of the head and neck have been corrected by shelf surgery in our hands. It would appear that many of our present surgical techniques are based upon plane diagrams which ignore the third dimension of depth.

The present study offers a simple technique for visualizing this third dimension and has proved of value. Still better techniques are anticipated. More objective data are needed throughout our diagnostic, progress, and end-result studies if our understanding and treatment of this difficult problem is to be improved.

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ROENTGENOGRAPHIC STUDY OF THE INCLINATION OF THE LATERAL PELVIC WALL AND THE INTERACETABULAR DISTANCE IN NORMAL ADULT PELVES

BY ROBERT AUSTIN MILCH, M.D., NEW YORK, N. Y.

Structurally considered, the human pelvis may be divided into four general types: android (male), gynecoid (female), anthropoid (ape) and platypelloid (flat) [1, 6]. Most of the anatomical features which permit differentiation of these four types are those of the *interior* of the true pelvis, of the anteroposterior and transverse diameters of the pelvic inlet, the mid-pelvis, and the pelvic outlet. As such, the clinical value of pelvic typing is virtually exclusively of obstetrical concern. The exterior of the pelvis, which has no obstetrical importance, has been accorded only minimal clinical attention. Practically no information is available concerning either the lateral pelvic wall or the interacetabular distance.

The proper mensuration of these latter anatomical entities, however, is of compelling importance to the orthopaedic surgeon, particularly in consideration of the kinesiological problems attendant upon osteotomy at the upper end of the femur. Indeed, it has been clearly shown [2, 3, 4] that the angle of inclination of the lateral pelvic wall directly determines a critical value for the angle of the *mechanical* neck of the osteotomized femur (the *postosteotomy angle*), beyond which increasing stability results in concomitantly decreasing mobility at the hip. It has been observed, furthermore, that the apparent lengthening resulting from unilaterally performed upper femoral osteotomy (when the contralateral hip is freely movable) is directly related to the length of the interacetabular line and to the angle formed between the interacetabular line and a line drawn perpendicular to the mechanical axes of both erect and parallel femora [5].

The present study was undertaken, therefore, in an attempt to discover (1) whether or not there is any relationship between these entities of the exterior of the pelvis and those of the interior, in relation to the four fundamental pelvic types, and (2) whether or not there is any significant difference between these external measurements for pelves of adult men and adult women.

MATERIAL

One hundred anteroposterior roentgenograms of female pelves were selected at random from the pelvimetry files of the Sloan Hospital for Women, Columbia-Presbyterian Medical Center, and 100 anteroposterior roentgenograms of male pelves were selected at random from the private files of Dr. Henry Milch. All of the roentgenograms of the female subjects were made with target distances of about forty inches. The target distance varied between thirty-six and forty-two inches in all roentgenograms of male subjects.

The female subjects were all pregnant and were at or near term. They varied in age from seventeen to forty-three years. The male subjects varied in age from thirty-one to seventy-eight years. All patients had clinically and roentgenographically normal hips. Roentgenograms of patients with known skeletal disease anywhere in the body were specifically discarded. If there were any gross evidences of rotation of the patient before the film cassette, as manifested by the disproportionate size of the iliac alae or of the obturator foramina, the roentgenograms were likewise discarded.

METHODS

The angle of inclination of the lateral pelvic wall was determined (1) by drawing a line between the superior acetabular margins of each hemipelvis (interacetabular line),

FIG. 1

Anteroposterior roentgenogram of the pelvis of a normal female subject, twenty-one years old. The line AC represents the interacetabular distance, and α is the angle of inclination of the lateral pelvic wall on either side. The line AB is the true horizontal (that is, the line drawn perpendicular to the lines PP and $P'P'$ which are parallel to the mechanical axes of both erect and parallel femora). D, which is trigonometrically equal to the product of the interacetabular distance and the sine of the angle between the interacetabular line and the true horizontal, angle θ, represents the amount of downward inclination of the entire pelvis and quite accurately accounts for the amount of apparent change in limb length following an upper femoral osteotomy performed for unilateral hip-joint disease.

(2) by drawing a line between the superior acetabular margin of one side and the most lateral portion of the body of the ipsilateral ischium (ischio-acetabular line), and (3) by constructing a perpendicular to the interacetabular line so that it extended downward beyond the ischio-acetabular line (Fig. 1). The larger angle between the ischio-acetabular line (representing the pelvic wall against which the osteotomized femur must rest) and the perpendicular to the interacetabular line (representing both the erect position and the mechanical axis of the extremity) defined the angle of inclination of the lateral pelvic wall. It was measured in a clockwise direction on the left side and in a counter-clockwise direction on the right. In most instances, the angles so constructed were equal on both sides. For differences of 5 degrees or less, the mean of the two values was accepted.

The interacetabular line was directly measured from the most lateral clearly defined roentgen shadow of either superior acetabular margin.

All of the female pelves had previously been evaluated by others in so far as the pelvic types were concerned. Refinements of classification, especially of mixed types, were omitted in this study and only the predominant type of the pelvis was considered.

TABLE I

INTERACETABULAR DISTANCE AND ANGLE OF INCLINATION OF THE LATERAL PELVIC WALL IN NORMAL FEMALE SUBJECTS

Type	Interacetabular Distance (*Centimeters*)					Angle of Inclination of the Pelvic Wall (*Degrees*)			
	No. of Pelves	Mean	Standard Deviation	Maximum	Minimum	Mean	Standard Deviation	Maximum	Minimum
Android	37	24.1	1.7	26.0	18.3	207.4	3.9	216	199
Gynecoid	32	24.2	1.7	27.5	20.7	206.4	5.4	216	197
Anthropoid	23	23.1	0.9	25.3	21.3	204.4	4.7	213	198
Platypelloid	8	24.4	1.0	26.0	22.7	207.0	2.9	213	202
	100	24.0	1.6	27.5	18.3	206.4	4.7	216	197

RESULTS

Of the 100 female pelves, thirty-seven were predominantly android, thirty-two were gynecoid, twenty-three were anthropoid, and eight were platypelloid. The mean interacetabular distance in this group was 24.0 centimeters, with a standard deviation of 1.6 centimeters. The mean angle of inclination of the lateral pelvic wall was 206.4 degrees, with a standard deviation of 4.7 degrees (Table I). Pelves of the android type showed a mean interacetabular distance of 24.1 centimeters, with a standard deviation of 1.7 centimeters, and a mean angle of inclination of the lateral pelvic wall of 207.4 degrees, with a standard deviation of 3.9 degrees; pelves of the gynecoid type showed a mean interacetabular distance of 24.2 centimeters, with a standard deviation of 1.7 centimeters, and a mean angle of inclination of the lateral pelvic wall of 206.4 degrees, with a standard deviation of 5.4 degrees; pelves of the anthropoid type showed a mean interacetabular distance of 23.1 centimeters, with a standard deviation of 0.9 centimeters, and a mean angle of inclination of the lateral pelvic wall of 204.4 degrees, with a standard deviation of 4.7 degrees; and pelves of the platypelloid type showed a mean interacetabular distance of 24.4 centimeters, with a standard deviation of 1.0 centimeter, and a mean angle of inclination of the lateral pelvic wall of 207.0 degrees, with a standard deviation of 2.9 degrees.

The maximum length of the interacetabular distance in all of the roentgenograms

TABLE II

COMPARISON OF THE OBSERVED AND "STATISTICALLY MAXIMAL" * VALUES OF THE INTERACETABULAR DISTANCE AND THE ANGLE OF INCLINATION OF THE LATERAL PELVIC WALL IN NORMAL FEMALES

	Interacetabular Distance (*Centimeters*)		Ideal Percentage **	Angle of Inclination of Lateral Pelvic Wall (*Degrees*)	
	Calculated	Cases Included (*Per cent.*)		Calculated	Cases Included (*Per cent.*)
m (mean)	24.0			206.4	
m + 1 SD ***	25.6	86.	68.3	211.1	73.
m + 1.4 SD	26.2	94.		213.0	91.
m + 2 SD	27.2	98.	95.4	215.8	98.
m + 3 SD	28.8	100.	99.7	220.5	100.

* "Statistically maximal" values are considered to be those greater than the mean value by n standard deviations, for example, m + 1 SD or m + n SD.

** Ideal percentage indicates that in a normal or moderately skewed distribution curve, 68.3 per cent. of the population of data will fall within 1 standard deviation of the mean, 95.4 per cent. will fall within 2 standard deviations of the mean, and 99.7 per cent. will fall within 3 standard deviations of the mean.

*** Standard deviation.

TABLE III

COMPARISON OF THE OBSERVED AND "STATISTICALLY MAXIMAL" VALUES OF THE INTERACETABULAR DISTANCE AND THE ANGLE OF INCLINATION OF THE LATERAL PELVIC WALL IN NORMAL MALES

	Interacetabular Distance (*Centimeters*)		Ideal Percentage	Angle of Inclination of Lateral Pelvic Wall (*Degrees*)	
	Calculated	Cases Included (*Per cent.*)		Calculated	Cases Included (*Per cent.*)
m (mean)	25.9			211.4	
m + 1 SD	27.6	87.	68.3	217.2	80.
m + 1.4 SD	28.3	93.		219.5	94.
m + 2 SD	29.3	98.	95.4	223.0	99.
m + 3 SD	31.0		99.7	228.8	

was 27.5 centimeters, and the minimum length was 18.3 centimeters. The maximum angle of inclination of the lateral pelvic wall was 216 degrees and the minimum angle was 197 degrees (Table I). Eighty-six per cent. of the interacetabular distances fell within 1 standard deviation (m ± 1 SD) of the mean, 94 per cent. fell within 1.4 standard deviations of the mean, 98 per cent. within 2 standard deviations of the mean, and 100 per cent. fell within 3 standard deviations greater than the mean. Seventy-three per cent. of the subjects had angles of inclination of the lateral pelvic wall falling within 1 standard deviation of the mean, 91 per cent. within 1.4 standard deviations of the mean, 98 per cent. within 2 standard deviations of the mean, and 100 per cent. within 3 standard deviations greater than the mean (Table II).

The differences between the means of both the interacetabular distances and the angles of inclination of the lateral pelvic wall of the various types were not statistically significant. Thus, it is apparent that in pelves of normal adult female subjects, there is no significant difference in either the mean interacetabular distance or in the mean angle of inclination of the lateral pelvic wall among any of the four fundamental pelvic types. It appears that variation *within* the pelvis is not related to differences in at least two of the *external* features of the pelvis. Furthermore, it will be seen that the data here obtained somewhat more closely approximate the mean than do the data for the theoretical, or ideal, distribution curve.

In the 100 male pelves, no attempt was made to ascertain the clinical type of the pelvis. The mean interacetabuiar distance was 25.9 centimeters, with a standard deviation of 1.7 centimeters. The maximum distance encountered was 31.4 centimeters, and the minimum distance was 22.1 centimeters (Table IV). Eighty-seven per cent. of the pelvic measurements fell within 1 standard deviation of the mean, 93 per cent. within 1.4 standard deviations of the mean, and 98 per cent. within 2 standard deviations of the mean (Table III). The mean value of the angle of inclination of the lateral pelvic wall was 211.4 degrees, with a standard deviation of 5.8 degrees (Table IV). Eighty per cent.

TABLE IV

COMPARISON OF THE INTERACETABULAR DISTANCE AND THE ANGLE OF INCLINATION OF THE LATERAL PELVIC WALL IN 100 NORMAL MALE AND 100 NORMAL FEMALE SUBJECTS

Sex	No. of Subjects	Interacetabular Distance (*Centimeters*)				Angle of Inclination of Lateral Pelvic Wall (*Degrees*)			
		Mean	Standard Deviation	Maximum	Minimum	Mean	Standard Deviation	Maximum	Minimum
Male	100	25.9	1.7	31.4	22.1	211.4	5.8	227	202
Female	100	24.0	1.6	27.5	18.3	206.4	4.7	216	197

TABLE V

MEAN, MAXIMUM (M + 3 SD), AND MINIMUM (M − 3 SD) AMOUNTS OF APPARENT CHANGE IN LIMB LENGTH RESULTING FROM UPPER FEMORAL OSTEOTOMY PERFORMED FOR UNILATERAL HIP-JOINT DISEASE *

Θ (*Degrees*)	Amount of Apparent Change in Limb Length (*Centimeters*)					
	Males			Females		
	Mean (25.9)	Maximum (31)	Minimum (20.8)	Mean (24)	Maximum (28.8)	Minimum (19.2)
1	0.5	0.6	0.4	0.5	0.6	0.4
5	2.3	2.7	1.8	2.2	2.8	1.7
10	4.4	5.3	3.5	4.2	4.9	3.3
15	6.7	8.1	5.4	6.2	7.5	5.0
20	8.8	10.5	7.1	8.1	9.8	6.6
25	10.8	13.0	8.7	10.1	12.1	8.1
30	12.9	15.5	10.4	12.0	14.4	9.6

* Θ refers to the angle of downward inclination of the entire pelvis. The amount of apparent change in limb length (D) equals $a \cdot \sin \Theta$ where a is the length of the interacetabular line. The numbers in parentheses refer to the values of the mean, maximum (m +3 SD), and minimum (m −3 SD) values for the apparent change in limb length (D).

of the pelves fell within 1 standard deviation of the mean, 94 per cent. within 1.4 standard deviations of the mean, and 99 per cent. within 2 standard deviations of the mean (Table III).

Calculation of the standard deviation of the differences between the means of the interacetabular distances and the angles of inclination of the lateral pelvic wall in both male and female subjects reveals that there is, statistically, a highly significant ($P < 0.001$) difference between the sexes in so far as both of these pelvic measurements are concerned (Table IV).

DISCUSSION

Some most interesting consequences follow from these observations. First, the data provide a basis for determining the amount of disparity in limb length which may be expected following upper femoral osteotomy in patients with unilateral hip-joint disease. Since it has been shown [5] that the amount of limb disparity (D) is equal to the product of the length of the interacetabular distance (a) and the sine of the angle (θ) between the interacetabular line and the line drawn perpendicular to the mechanical axes of both erect and parallel femora (that is, the true horizontal), and since, in any normal or moderately skewed distribution curve, 99.7 per cent. of the population of data will fall within plus or minus 3 standard deviations of the mean (m ± 3 SD), it is evident that for any angle θ it is possible to determine accurately the maximum and minimum amounts of disparity in limb length which are likely to occur in virtually all cases.

Although any value of θ is theoretically possible, the maximum angle consonant with vertical stance is about 20 degrees. Twenty-five degrees of downward inclination of the pelvis is practically never attained without some abduction of the limb. Data are presented, nevertheless, for angles of downward inclination of the entire pelvis from 1 to 30 degrees (Table V). Examination of these reveals that the limit of disparity in limb length is, in the presence of vertical stance, about 10 centimeters for *all* patients. The minimum amount of change and the maximum amount of change which may be expected in 99.7 per cent. of all patients differ only 3 to 4 centimeters at the most. The mean amount of change differs from both the maximum and minimum amounts by only about 1 to 2 centimeters.

Second, it is apparent that there is no correlation, at least in those (female) pelves clinically evaluated as to the predominant pelvic type, between the interior of the true

pelvis (the anatomical features of which determine the clinical type of the pelvis) and the exterior characteristics of the lateral pelvic wall and the interacetabular distance. Furthermore, there is a definite and statistically highly significant difference between these latter two anatomical entities in pelves of female and male subjects, the males tending to more flattened pelvic walls and longer interacetabular distances.

Third, a most interesting suggestion offers itself in the consideration of the width of the hips. There is no question but that some patients clinically have narrower and others wider hips. As a matter of fact, however, it would appear that the width of the hips is not due to anatomical features directly related to the true pelvis but rather to such other factors as variations in the length of the anatomical neck of the femur, the flare of the iliae, the extent of the soft tissues overlying these areas, or any combination of these.

SUMMARY AND CONCLUSIONS

One hundred anteroposterior roentgenograms of normal female pelves and 100 anteroposterior roentgenograms of normal male pelves were studied from the point of view of the interacetabular distance and the angle of inclination of the lateral pelvic wall.

Male pelves were characterized by a mean interacetabular distance of 25.9 centimeters, with a standard deviation of 1.7 centimeters. Female pelves were characterized by a mean interacetabular distance of 24.0 centimeters, with a standard deviation of 1.6 centimeters. No significant difference was found among the four fundamental pelvic types (android, gynecoid, anthropoid, and platypelloid) in the female subjects.

The mean angle of inclination of the lateral pelvic wall in male subjects was 211.4 degrees, with a standard deviation of 5.8 degrees. The angle of inclination of the lateral pelvic wall in female subjects was 206.4 degrees, with a standard deviation of 4.7 degrees. There was no significant difference among the angles of the pelvic wall in any of the four primary pelvic types.

The difference in mean interacetabular distance and the mean angle of inclination of the lateral pelvic wall between male and female subjects was statistically highly significant ($P < 0.001$).

It is suggested that there is no correlation between the distinguishing anatomical features of the interior of the true pelvis and those of the exterior of the pelvis here discussed.

It is further suggested that the difference in clinical hip width among male and female subjects, respectively, is not due to the anatomical features of the true pelvis.

Data are presented for the statistically probable maximum and minimum amounts of apparent change in limb length which can be expected in virtually all patients following upper femoral osteotomy performed for unilateral disease of the hip joint.

NOTE: The writer would like to express his most sincere thanks to his father, Dr. Henry Milch, of the Hospital for Joint Diseases, for first inspiring his interest in hip-joint disease and for his constant aid and stimulation during the undertaking of this project; to Dr. Charles M. Steer, of the Sloan Hospital for Women of the Columbia-Presbyterian Medical Center, for permission to view films of the pelvimetry files under his direction and for his constant encouragement and many suggestions during this study.

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EPIPHYSEODESIS FOR EARLY SLIPPING OF THE UPPER FEMORAL EPIPHYSIS*

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Characteristic physical findings and roentgenographic changes enable one to recognize slipping of the upper femoral epiphysis early, before there is appreciable displacement or before this has progressed to more than slight degree. While further displacement may not be inevitable, a sudden acute slipping with complete displacement is always feared, or a progressing deformity is likely to take place, which may result in severe impairment of function of the hip.

Orthopaedic surgeons are agreed upon the necessity of treatment during the early stage of slipping of the upper femoral epiphysis, but are not in agreement on the methods to be employed. Although spontaneous fusion of the epiphysis eventually occurs, this may require more than two years. The average length of time for fusion under conservative treatment has been found by Cleveland and his co-authors to be 19.8 months after the onset of symptoms. During this long critical period, some effective means for protection of the hip against strain or for fixation of the epiphysis is required. Stimulation of prompt fusion is therefore desirable, for this precludes the risk of further deformity and lessens the period of disability. Although it is not directed primarily to increasing the blood supply to the femoral head in the preslipping stage, epiphyseodesis might be advantageous if deficiency of circulation to the head is an important factor in the cause and progression of slipping of the epiphysis. Perhaps new channels for improvement of circulation to the head from the neck of the femur may be provided by obliterating the barrier of the epiphyseal plate. If it could be demonstrated that this does occur, surgical fusion of the epiphysis might well be a major objective in the treatment of acute slipping with severe displacement which so frequently results in aseptic necrosis.

While recognizing the desirability of early fusion, the proponents of nailing the epiphysis *in situ* by means of a Smith-Petersen nail advocate this technique for stabilizing the epiphysis as a protection against further displacement, but not necessarily to promote fusion. Although Wilson reported that fusion takes place four to six months after nailing, others who follow this practice do not believe that nailing can be relied upon to stimulate fusion. Klein and his associates stated that fusion occurs within six to eighteen months after nailing, and Joplin found that the nail does not always arrest growth of the epiphysis. Wagner inserted the nail for protection of the hip, but reported that it did not hasten fusion. Cleveland and his associates had good results by nailing *in situ*, but they did not say whether or not fusion was stimulated. Key did not believe that inserting a nail or drilling across the epiphyseal plate can be depended upon to fuse the epiphysis. Rüther reported that metal nails failed to lead to a premature fusion of the epiphysis in experimental animals, but that a graft of bone from the trochanter into the head did promote fusion. Badgley inserted a Smith-Petersen nail for protection only, not for fusion, but reported 25 per cent. poor results in nailing minimal slipping in sixteen patients. In reporting upon the experience of the Staff at the Campbell Clinic, Boyd, Ingram, and Bourkard stated that they preferred the use of three Knowles pins, because of the surgical trauma incidental to driving a nail through the comparatively dense neck in the age group in which this condition occurs and because fixation is more secure with the three pins than with a nail. They did not state how soon fusion occurred after this type of fixation, but

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 30, 1953.

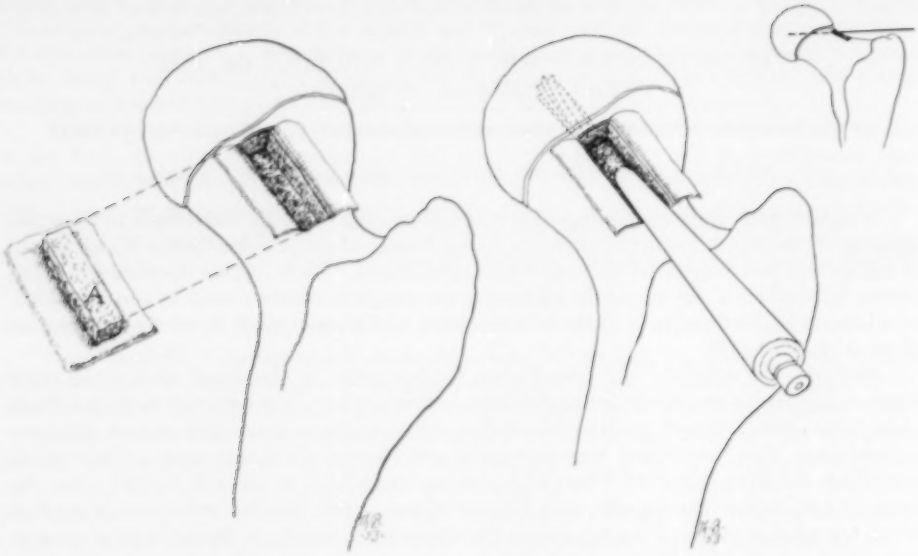

FIG. 1 FIG. 2

Figs. 1 to 5: Illustrate the procedure of epiphyseodesis at the upper femoral epiphysis.
Fig. 1: A piece of cortical bone, *A*, is removed from the neck of the femur. This is to be replaced later.
Fig. 2: A hole, one centimeter in diameter, is drilled across the center of the epiphyseal plate. The inset shows the direction of the drill.

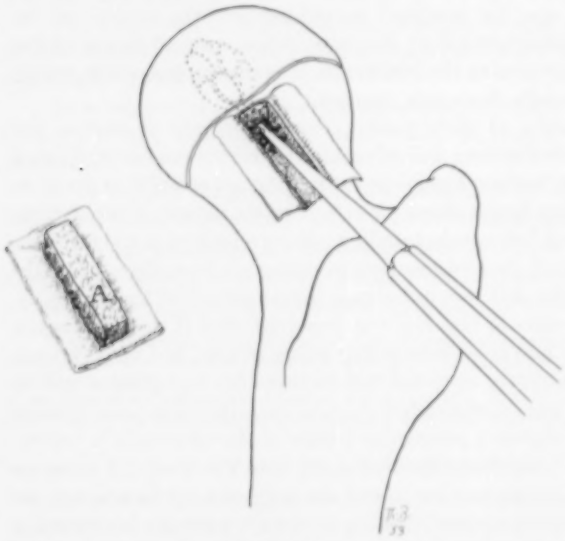

FIG. 3

The opening may be enlarged by means of a curette.

did say that their results were unsatisfactory in 12 per cent. of their cases. Howorth was opposed to nailing because the nail does not stimulate bone formation, and because he had observed degenerative changes in a fair percentage of the hips nailed.

It appears, therefore, that a nail placed across the epiphyseal plate does not greatly hasten fusion of the epiphysis in the so-called preslipping stage, and that the chief function of the nail is that of fixation to prevent further displacement. Poor results are not always caused by improper nailing. Even if there has been no apparent flaw in technique, the nail may become loose or fail to hold, and even with adequate fixation, degenerative changes causing pain and stiffness may sometimes occur.

While metallic fixation of the epiphysis is commonly practised, many contemporary writers prefer other, more conservative methods of treatment. Among these are Green,

Ghormley and Fairchild, Ober, Milch, Rabinowitz, and Kleinberg. McCarroll was not convinced that nailing is necessary in all cases of minimal slipping, because many heal with bed rest and traction.

Although it may not happen frequently, we have had the experience, as have others, of sudden acute slipping occurring in patients under conservative treatment, although they were presumably following orders. It has been a very common experience, moreover, to note a gradually increasing displacement, progressing steadily or intermittently, while the patient has been under treatment with crutches or a brace. This has also been said to occur during or after treatment with a plaster spica. A more effective means is preferable for prevention of displacement and for hastening the process of healing.

Because of the observation that insertion of a Smith-Petersen nail or drilling across the epiphyseal plate did not considerably shorten the period required for fusion and because of several poor results accompanying this treatment, one of the writers in 1943 began treating patients with slipping in the early stages by a direct operative approach to bring about prompt fusion of the epiphysis. This offered advantages even though it required a wider surgical exposure. The results of ten operations were reported in 1949[6]. The results in all were excellent, with normal motion and with roentgenographic evidence of fusion within three months after operation. Until that time we did not know that Howorth had been treating such cases of early slipping by a similar method of operative fusion, and that in a much larger number of cases he had also noted fusion within three months. In discussion Key [10] expressed the opinion that a graft of bone placed across the center of the epiphyseal plate could not be relied upon to cause fusion of the epiphysis at the hip any more than nailing or drilling. Sullivan recently stated that he had employed the technique described by Howorth three or four times, and in each case union of the epiphysis took place very promptly, with complete cure of symptoms.

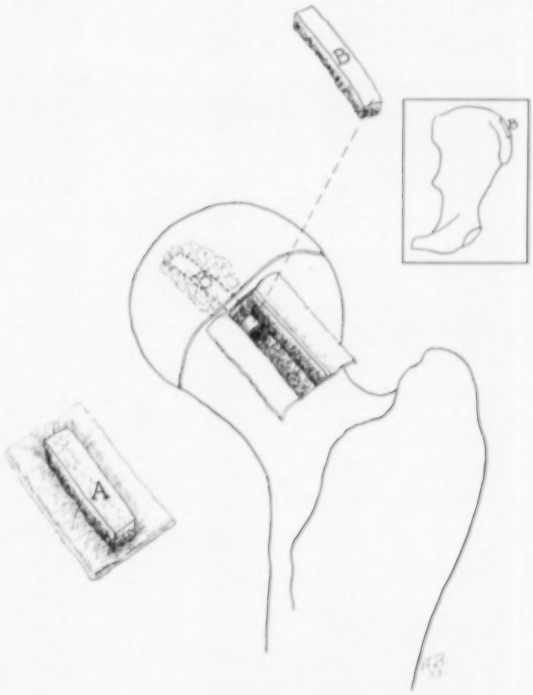

FIG. 4

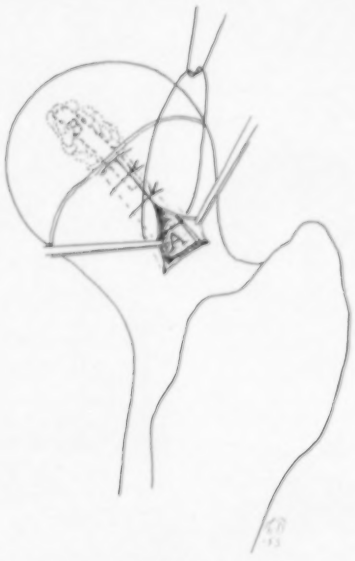

FIG. 5

Fig. 4: Small pieces of cancellous bone from the crest of the ilium are impacted into the hole and are driven across the epiphyseal plate, or a solid peg of cancellous bone, *B*, may be driven in.

Fig. 5: The piece of cortical bone, *A*, is replaced and the periosteum is sutured.

FIG. 6-A

FIG. 6-B

FIG. 6-C

FIG. 6-D

Fig. 6-A: November 5, 1943. J. Z., boy, fourteen years old. He had a slipped epiphysis in the right hip with symptoms for two months. An epiphyseodesis was done on November 24, 1943, and he was immobilized in a plaster spica for three months.

Fig. 6-B: February 23, 1944. The epiphysis was fused three months after operation.

Fig. 6-C: March 1, 1946. Two years after operation the epiphysis on the normal side had not yet fused.

Fig. 6-D: September 15, 1950. Showing the result seven years after operation.

FIG. 7-A

FIG. 7-B

FIG. 7-C

FIG. 7-D

Fig. 7-A: May 5, 1944. J. H., boy, thirteen years old. The duration of symptoms had been one year. The roentgenogram was more suggestive of coxa vara, but the symptoms and physical findings were identical to those in slipping of the epiphysis. Epiphyseodesis of the right hip was done on June 14, 1944. No postoperative fixation was applied.

Fig. 7-B: August 29, 1944. The epiphysis was fused ten weeks after operation.

Fig. 7-C: June 1, 1945. The epiphysis on the normal side had not fused one year after operation.

Fig. 7-D: September 5, 1947. Result three years after operation.

FIG. 8-A

FIG. 8-B

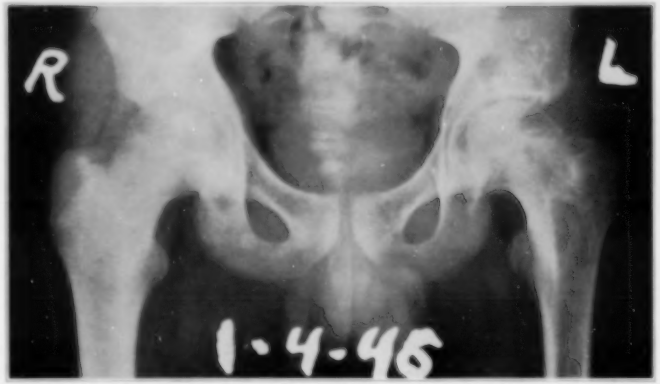

FIG. 8-C

FIG. 8-D

Fig. 8-A: July 6, 1945. H. H., boy, fifteen years old. There was slipping of the epiphysis on the left with symptoms for seven weeks. Epiphyseodesis was done on August 15, 1945, and a plaster spica was applied for two months.

Fig. 8-B: November 16, 1945. The epiphysis was fused three months after operation.

Fig. 8-C: January 4, 1946. Roentgenogram made four and one-half months after operation.

Fig. 8-D: February 3, 1950. Showing the result four and one-half years after operation.

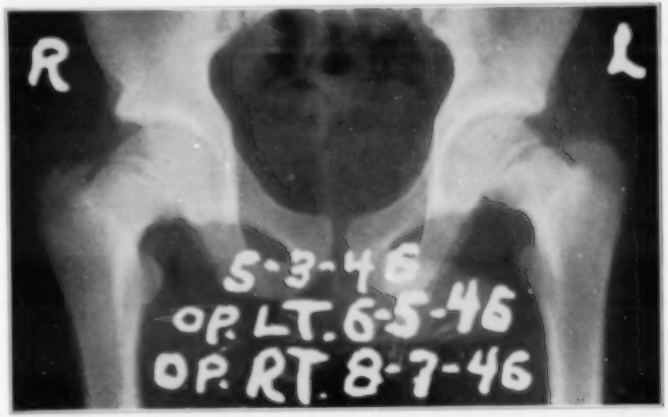

FIG. 9-A

FIG. 9-B

FIG. 9-C

FIG. 9-D

Fig. 9-A: May 3, 1946. G. S., boy, thirteen years old, with bilateral slipping. He had had symptoms in the left hip for three months and in the right hip for one month. An epiphyseodesis was done on the left hip on June 5, 1946, and on the right hip on August 7, 1946. No postoperative fixation was used.

Fig. 9-B: July 17, 1946. Roentgenogram made six weeks after operation on the left hip.

Fig. 9-C: September 10, 1946. Roentgenogram made three months after operation on the left hip and one month after operation on the right hip.

Fig. 9-D: December 21, 1951. Roentgenograms showing result five and one-half years after epiphyseodesis on both hips.

Further experience with the operation of inserting a centrally directed graft of cancellous bone across the epiphyseal plate from the neck of the femur into the epiphysis continues to show excellent results in all patients and prompted a report with a description of the operative technique employed. All patients were examined for end-result evaluation independently and objectively by Dr. Charles H. Herndon, who assembled the data pertaining to these results. Nineteen operations for epiphyseal fusion were done upon fifteen patients. Four patients had bilateral involvement. The average period of postoperative observation was 2.7 years. The longest period was seven years and the shortest six months. The average age at the time of operation was thirteen years; the youngest was eleven years old, and the oldest was sixteen years old. Thirteen patients were males and two were females. All patients limped and had limitation of motion with varying degrees of pain. In seventeen cases there was only minimal slipping or widened and irregular epiphyseal lines, with an average of nine weeks' duration of symptoms before operation. Two patients had more severe slipping, and both had had symptoms for one year.

The average interval between operation and partial weight-bearing in all cases was ten weeks; full weight-bearing was allowed at an average of eighteen weeks. This includes, however, the patients seen early in the series who were treated more cautiously by rest in bed for two to three months after operation, followed by a Thomas walking splint. The interval before ambulation and weight-bearing are allowed has now been considerably reduced.

The average time before fusion of the epiphysis as seen by roentgenogram was 2.3 months. The shortest time was four weeks; the longest was 4.5 months. Fusion in this latter case probably occurred sooner, but it was not demonstrated earlier because of a long interval between roentgenograms. In six cases fusion on the normal side took place an average of 2.8 years later than on the side operated upon. In the other cases the condition was either bilateral, so that comparison with a contralateral normal hip was not possible, or the epiphysis on the normal side was still open when the patient was last seen.

The age of the patient at the time of operation bore no relationship to the time required for fusion to take place. The average time for fusion in the three youngest patients was seven weeks, and the average time for fusion in the three oldest patients was eight weeks. There was no relationship between the duration of symptoms before operation and the time required for fusion afterwards. The average time for fusion in the three patients with the shortest duration of symptoms was 10.3 weeks as compared with 9.7 weeks in the three patients with the longest duration of symptoms. In other words, the hastening of fusion of the epiphysis was brought about by the operation, and its occurrence a short time afterward was not due to the fact that the patient was older and approaching the normal age for fusion or to the fact that spontaneous fusion, possibly stimulated by the slipping itself, was already well in progress at the time of operation.

The clinical and roentgenographic results are excellent in all cases. No patient has pain, limp, or any limitation of activities. Motion is normal in all but two patients. In both of these there is only slight limitation of internal rotation as compared with the normal side, and in both there had been more than minimal slipping at the time of operation and the duration of symptoms had been one year. In one of these the displacement had been fairly severe, and the major obstruction to a considerable limitation of motion was removed from the neck of the femur at the time of operative fusion, with immediate improvement of motion.

In no case has there been any increase in displacement over that present at the time of operation. There are normally appearing bony trabeculation, homogeneous density, and smooth articular surfaces in all cases, with no suggestion of aseptic necrosis or other degenerative changes. In five cases the involved extremity is one-quarter to one-half inch shorter than the normal extremity.

FIG. 10-A

FIG. 10-B

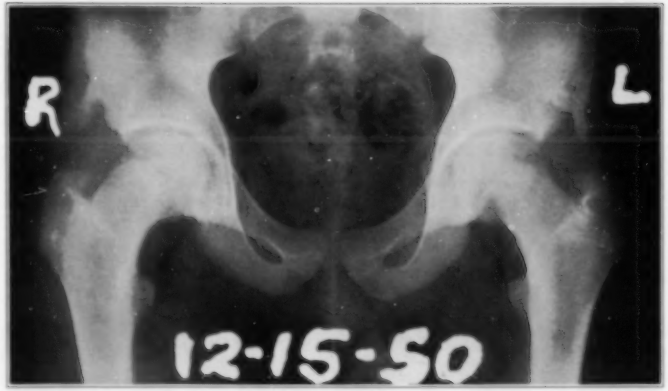

FIG. 10-C

FIG. 10-D

Fig. 10-A: April 28, 1950. J. L., boy, thirteen years old, with bilateral slipping. Symptoms had been present at the left hip for eight weeks. At this time there were no symptoms in the right hip. Epiphyseodesis was done on the left hip on May 10, 1950.

Fig. 10-B: September 15, 1950. Epiphysis of the left hip was fused. Symptoms at the right hip had been present for three weeks.

Fig. 10-C: December 15, 1950. Less than three months after operation (September 27, 1950) the epiphysis at the right hip was also fused. Light traction only had been applied for three weeks after each operation.

Fig. 10-D: February 20, 1953. Roentgenogram showing result almost three years after first operation.

FIG. 11-A

FIG. 11-B

FIG. 11-C

FIG. 11-D

Fig. 11-A: August 18, 1950. R. S., boy, twelve years old, with slipping of the epiphysis in the left hip with symptoms for seven weeks. An epiphyseodesis was done on August 23, 1950, and a plaster spica was applied for four weeks.

Fig. 11-B: September 27, 1950. The epiphysis was fused five weeks after operation.

Fig. 11-C: August 17, 1951. Roentgenogram made one year after operation.

Fig. 11-D: January 2, 1953. Showing the result more than two years after operation. The epiphysis on the normal side was not yet fused.

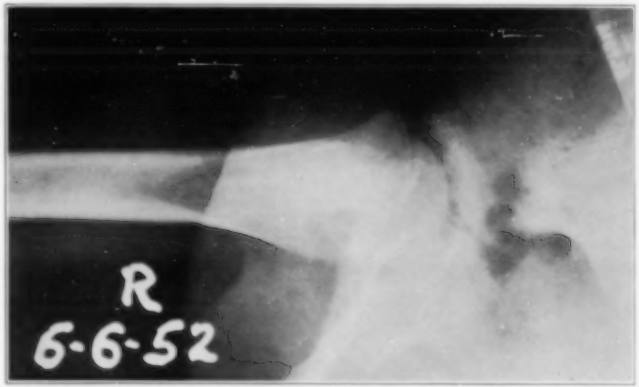

FIG. 12-A

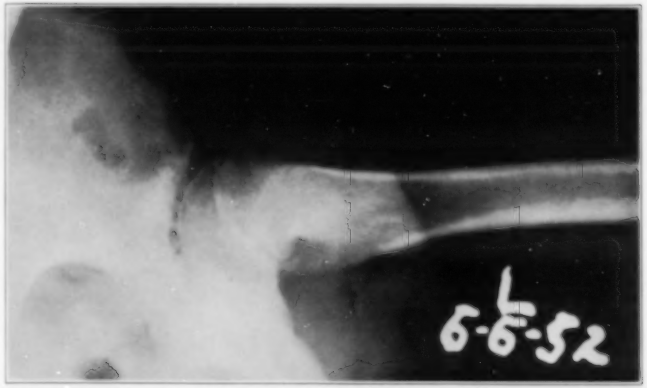

FIG. 12-B

FIG. 12-C

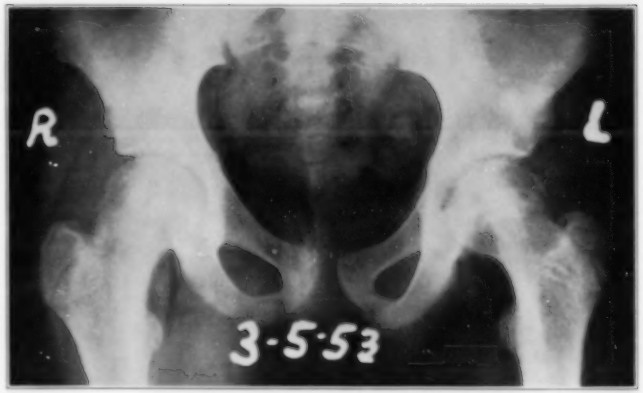

FIG. 12-D

Figs. 12-A and 12-B: June 6, 1952. J. S., girl, eleven years old. Acute slipping with marked displacement and complete disability had occurred in the right hip two weeks before, and moderate pain and disability had been present in the left hip for four months.

Fig. 12-C: September 3, 1952. Roentgenogram made ten weeks after open reduction, with a centrally placed cancellous-bone graft and a plaster spica applied to the right hip, and seven weeks after epiphyseodesis on the left hip, to which no postoperative fixation had been applied.

Fig. 12-D: March 5, 1953. Result nine months after epiphyseodesis on the right hip and eight months after epiphyseodesis on the left hip.

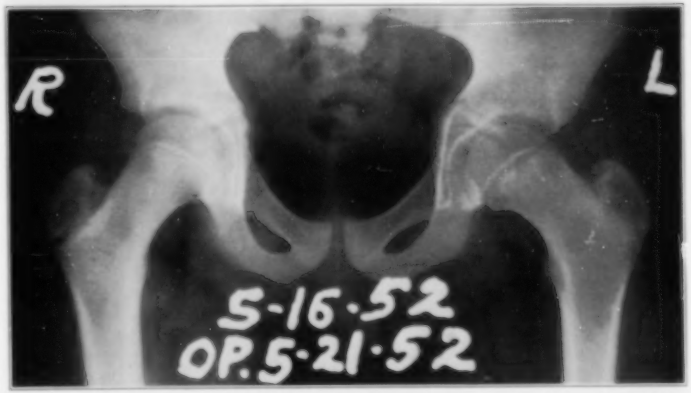

FIG. 13-A

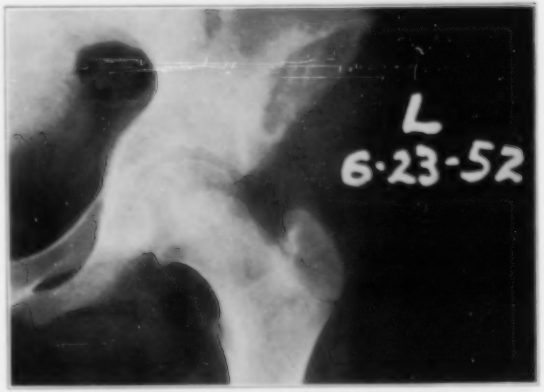

FIG. 13-B

FIG. 13-C

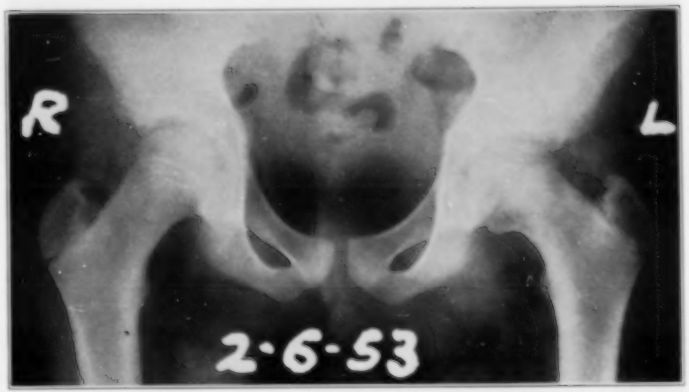

FIG. 13-D

Fig. 13-A: May 16, 1952. P. C., boy, thirteen years old. Slipping of epiphysis in the left hip with symptoms for five months. Epiphyseodesis was done on May 21, 1952, and a plaster spica was applied for two weeks.

Fig. 13-B: June 23, 1952. One month after operation there was fusion through the central portion where the graft had been inserted.

Fig. 13-C: Roentgenogram made November 7, 1952, five and one-half months after operation.

Fig. 13-D: February 6, 1953. Roentgenogram made nine months after operation.

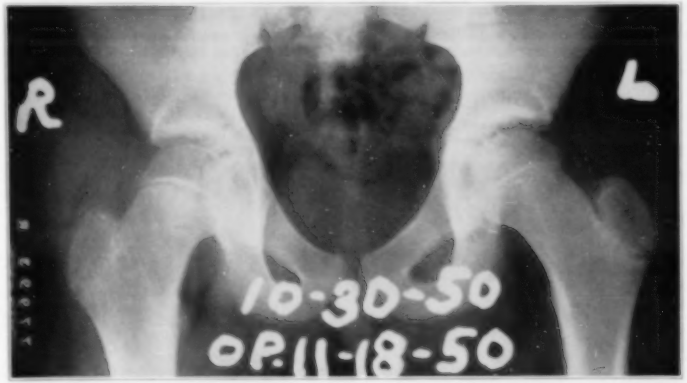

FIG. 14-A

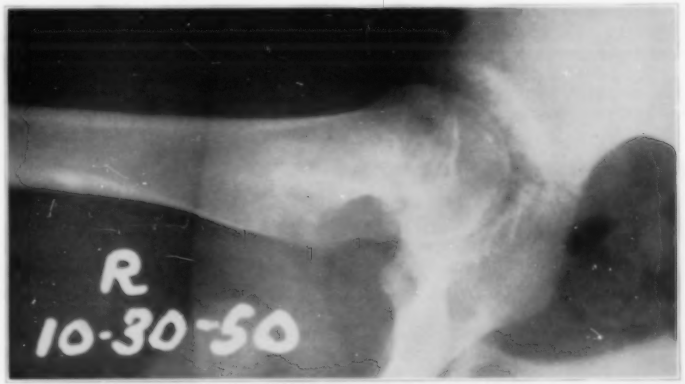

FIG. 14-B

FIG. 14-C

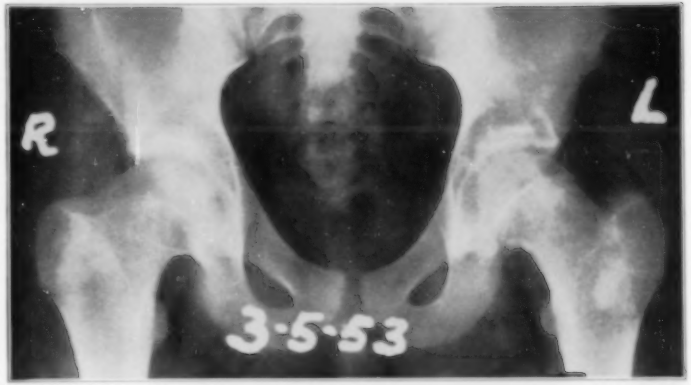

FIG. 14-D

Figs. 14-A and 14-B: October 30, 1950. W. T., a boy, fifteen years old, with bilateral slipping. Symptoms in the right hip had been present for two months. There were no symptoms in the left hip.

Fig. 14-C: December 26, 1952. Roentgenogram made two years after epiphyseodesis on the right hip. At this time symptoms in the left hip had been present for three months.

Fig. 14-D: March 5, 1953. Roentgenogram made ten weeks after operation on the left hip. No postoperative fixation had been used on either side.

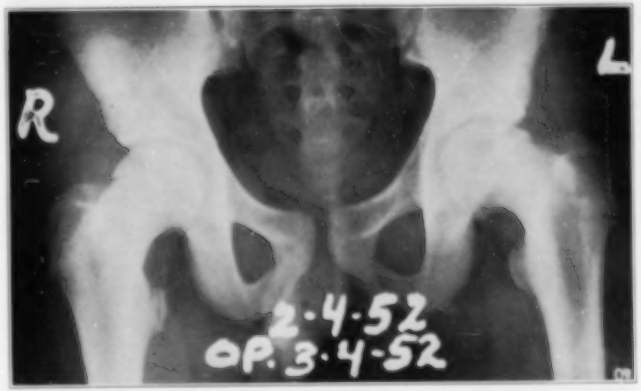

FIG. 15-A

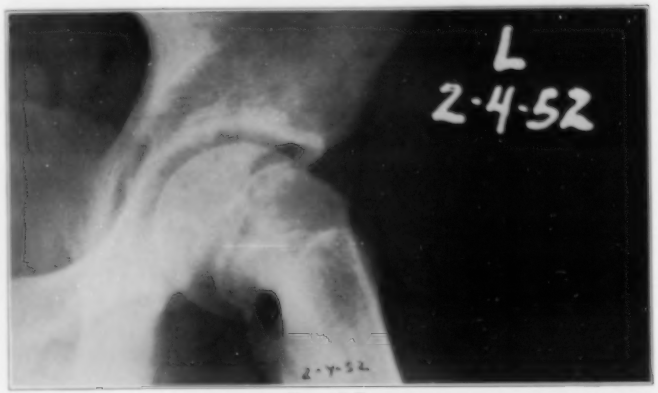

FIG. 15-B

FIG. 15-C

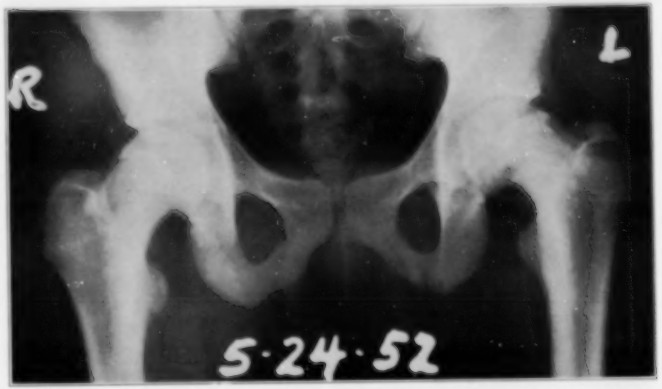

FIG. 15-D

Figs. 15-A and 15-B: February 4, 1952. R. B., boy, thirteen years old. There was rather severe displacement at the left hip in which symptoms had been present for one year. Flexion was limited to 60 degrees and the extremity was in severe external rotation. Note the angular prominence of bone at the neck of the femur. Operation was performed on March 4, 1952.

Fig. 15-C: March 20, 1952. Roentgenogram made sixteen days after operation. The bony prominence which was obstructing motion was removed and a portion of this cancellous bone was used as a graft placed across the center of the epiphyseal plate. No postoperative fixation was used.

Fig. 15-D: May 24, 1952. The epiphysis had fused and motion was normal except for slight limitation of internal rotation. There was no limp or appreciable disability.

DESCRIPTION OF THE OPERATION FOR EPIPHYSEODESIS

Exposure of the anterosuperior aspect of the neck of the femur is made through the Smith-Petersen approach. The capsule is incised longitudinally to expose the neck of the femur at its junction with the head. The periosteum is incised in the long axis of the neck, and at each end a short transverse incision is made. Excessive periosteal elevation should be avoided. It is not important to visualize the epiphyseal plate as long as one is oriented to its location. A rectangular-shaped section of bone cortex, about three centimeters long and one centimeter wide, is removed along the long axis of the neck of the femur. The epiphyseal plate is left intact and care should be taken not to injure the articular cartilage. This piece of cortical bone is laid aside to be replaced later. A twist drill or reamer, one centimeter in diameter, is then introduced into the gutter and is directed obliquely toward the center of the femoral head. A hole is made into the central portion of the head, deep enough to cross the epiphyseal plate. One can sense the relatively increased density as the drill enters the head. The opening may be enlarged somewhat by means of a curette, but no extensive curettage is attempted. Small pieces of cancellous bone, obtained from the crest of the ilium, are impacted into the depths of the hole, which is filled to the floor at the gutter in the neck of the femur. A solid peg of cancellous bone of appropriate size may also be driven in. The piece of cortex previously removed is then replaced, so that the surface of the femoral neck is left smooth and without any defect in bone. The periosteum and the capsule are sutured and the wound is closed.

No postoperative fixation is used other than temporary light traction for comfort and restraint. The posterior half of a plaster boot may be used instead, a horizontally and transversely placed length of wood being incorporated posterior to the ankle to steady the extremity and to prevent rotation while the patient is in bed. Pain and muscle spasm rapidly subside after operation, and there is soon a return to good active and passive motion. If one has complete confidence that the patient will not bear weight on the extremity, he is permitted to be ambulatory with crutches ten days after operation. Otherwise a plaster spica is applied and worn for four weeks. Perhaps this precautionary protection is better in most cases. Since this operation does not provide immediate fixation, no weight-bearing is permitted for six weeks. Full weight-bearing is not permitted until twelve weeks after operation, even if roentgenograms show obliteration of the epiphyseal plate before that time. It would seem, however, that there would be no objection to full weight-bearing as soon as roentgenograms show the epiphysis to be fused.

DISCUSSION

For those who are not satisfied with metallic fixation or with conservative treatment, the grafting procedure is recommended, as it unquestionably stimulates prompt fusion of the epiphysis. The average time for fusion after operation was 2.3 months, as compared with 19.8 months reported in patients treated by conservative methods and as compared with the doubtful hastening of fusion by metallic fixation. Operation for fusion of the epiphysis is preferable to conservative treatment because it lessens the period of disability and protective care required and prevents further displacement. The shortening or disturbance of growth following premature fusion in this age group is not of any consequence. No degenerative changes at the head of the femur or other harmful effects at the hip have occurred during the follow-up observations. Roentgenograms made soon after operation show a moderate but temporary demineralization throughout the epiphysis as compared with a relatively increased density before operation. This is indicative of a good blood supply. It is pertinent in this connection to mention one case in which a grafting procedure was done at the time of open reduction of an acute slipping. In this patient there had been sudden and complete displacement of the epiphysis, which was completely isolated from any blood supply other than that provided by the ligamentum

teres. Fusion was present at the end of eleven weeks in this case and the roentgenographic appearance and function of the hip when the patient was last seen were normal.

True end results cannot be determined until much later in life, but from the standpoint of function and roentgenographic appearance, it does not appear that disability is likely to occur later in those cases in which there had been no more than a minimal displacement originally. Although it is believed best to fuse the epiphysis in early cases of slipping, we do not, as yet, insist upon the necessity for immediate operation in every case without a short period of observation under protective treatment. Once the diagnosis has been firmly established, however, epiphyseodesis without further delay is recommended as offering fewer complications than temporizing and relying upon crutches or a brace, and as preferable to the unreliable results following long confinement to bed or protection in a plaster spica. While we do not deny that good results may be obtained by other methods of treatment, our own experiences and observations have led us to conclude that surgical fusion is preferable. Encouraging results suggest also that curettage of the epiphyseal plate and the insertion of a cancellous-bone graft from the neck of the femur into the head may be rational treatment at the time of reduction of acute slipping with marked displacement. Perhaps this may provide better circulation to the epiphysis and prevent aseptic necrosis, which so commonly follows treatment by reduction and immobilization alone. Further observations, of course, are required to confirm this.

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DISCUSSION

DR. H. R. MCCARROLL, ST. LOUIS, MISSOURI: The work of the authors and the earlier work of Dr. Howorth has shown that this operative procedure can be performed with apparent safety and with stimulation of more rapid fusion of the epiphyseal plate at the head of the femur. The question is whether or not the time saved in the fusion of the epiphysis justifies the amount of surgery which this procedure requires. In the preslipping stage or in the stage of minimal slipping, we can choose among four methods of treatment. The first of these is the conservative program in which bed rest with longitudinal traction together with internal rotation can be used, or immobilization in a plaster spica can be applied over a period of time. There is no question that further slipping can be prevented by means of traction. The objection to such therapy is obviously the length of time which the procedure requires. With such conservative measures, between twelve and twenty-four months are required for the epiphyses to fuse; in private practice this almost completely precludes the possibility of such treatment. In crippled children's clinics it has been used in many instances with satisfactory results and with little or no risk.

The second method is that of fixation of the capital epiphysis by means of a Smith-Petersen nail. The objection to the use of the Smith-Petersen nail in the past has been that it is possible to displace the epiphysis still further when the nail is introduced. I think that this hazard is more theoretical than real, although several instances of this complication have been reported.

The third procedure consists in fixation of the capital epiphysis by means of large threaded wires, Knowles pins, or Moore pins. These multiple pins can also adequately anchor the capital epiphysis and prevent further displacement. In time the epiphyseal plate will fuse and the result can be considered satisfactory. The objection to the use of these pins is the difficulty one encounters, not infrequently, in their placement. To introduce three or four such pins into the neck of the femur and symmetrically across the epiphyseal plate in a young child is not always easy.

This brings us to the fourth procedure possible in the treatment of this condition, that discussed by the authors. There seems to be little question that with the use of bone grafts we can expect more rapid fusion of the epiphyseal plate and, in the authors' hands at least, the results have been satisfactory and no instance of aseptic necrosis has been encountered. This seems a little strange in view of the amount of surgery involved. Such an operative procedure cannot be considered free from risk and, if it is established as a more or less routine method of treatment, unsatisfactory results will be encountered. In the hands of the average surgeon it would seem, therefore, that fixation of the capital epiphysis by means of the three-flanged nail or by means of threaded wires or pins represents a safer and more satisfactory procedure.

DR. M. BECKETT HOWORTH, NEW YORK, N. Y.: Dr. Heyman has presented a group of nineteen operations performed during the last ten years in which he has done a successful stimulation of fusion in the upper femoral epiphysis for early and later slipping. This is an interesting group of cases, well presented. I was impressed with the roentgenograms. I was also pleased to note that among the cases were one or two in which there had been a slipping of about half an inch; in these some of us might have been tempted to do an open reduction rather than merely to arrest the slipping where it was.

Our experience with epiphyseodesis for the upper femoral epiphysis dates back to 1930 and was first recorded in 1931 [a]; since that time we have studied nearly 300 cases operated upon by this method. Two hundred of them were reported in Quebec in 1948 [b] and another hundred have been operated upon since that time. Phemister [c], about the time when we were working on this problem, reported his operation, but his purpose, of course, was to stop growth, and our purpose was to stop slipping and to produce healing of the lesion, so that, although basically the operations were similar, the purposes of the operations were quite different. What are the indications for such a procedure in the upper femoral epiphysis? I consider that the operation might well be indicated for any child with an early slipping of the upper femoral epiphysis. If the slipping has gone as far as half an inch, there is still no objection to the operation. We have done it in such cases and found that it works and that the clinical results are more satisfactory than in most of the cases in which we attempted an open reduction through the neck, or an osteotomy.

The technique of the operation is somewhat similar to that of Dr. Heyman's. Instead of cutting a slot in the neck, we make a small triangular fenestration anteriorly through which we drill three holes across the epiphyseal plate, using the Nicola gouge. Then we remove three bone pegs from the ilium and insert them through these holes. Actually, if the epiphysis has slipped a little, the holes can be drilled more easily, because the head is displaced posteriorly and the pegs are aimed more directly toward the head.

Once the hip has been exposed the operative procedure is simple and the operative trauma is slight.

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(Continued on page 572)

FRACTURE-DISLOCATION OF THE ANKLE WITH THE FIBULA FIXED BEHIND THE TIBIA

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In 1947, Bosworth reported five cases of fracture-dislocation of the ankle in which the proximal fragment of the fibula became caught behind the flaring distal posterolateral portion of the tibia. In the first case, a recent fracture, reduction by manipulation was impossible. At open reduction, the reason for this was found to be the posterior displacement of the fibular-shaft fragment, which was held tightly in place behind the posterolateral tibial ridge by the tense interosseous membrane. By prying the fibula away from the tibia, reduction of the dislocation was accomplished with a loud snap. In a second case, also a recent fracture, similar treatment was used.

Dr. R. I. Harris, in discussing Dr. Bosworth's paper, showed an identical case in which open reduction was necessary. Dr. Bosworth also reported two old cases in which fusion of the ankle was necessary, and another in which late open reduction (at nine months) gave a satisfactory clinical result.

Having the advantage of this previous work, the authors were able to treat a similar displacement by closed reduction. To their knowledge, it was the seventh case on record, and the first to be treated by closed reduction.

A twenty-four-year-old male slipped while crossing a wet street. Other than the fact that he had caught his heel on the curb, the mechanism of injury was unknown. The ankle was grossly swollen, and the foot was dislocated posterolaterally. Roentgenograms (Figs. 1-A and 1-B) showed a fracture-dislocation of the ankle

FIG. 1-A

FIG. 1-B

Posterolateral dislocation of ankle.

Fig. 1-A: Anteroposterior roentgenogram, showing marked posterior displacement of the fibula behind the tibia. To the medial side of the medial malleolus is a large fragment of bone which, later roentgenograms showed, came from the medial portion of the medial malleolus and was avulsed by the periosteal expansion of the deltoid ligament.

Fig. 1-B: Lateral roentgenogram, showing the long spike of the fibula apparently securely lodged behind the posterior flare of the tibia. This view also shows the marked posterior displacement of the fibula.

FIG. 2-A

FIG. 2-B

After first manipulation.

Fig. 2-A: The ankle mortise is still wide, and the posterior displacement of the fibula can now be easily seen on this anteroposterior view. Note the small plaque of bone on the medial portion of the medial malleolus.

Fig. 2-B: In this lateral roentgenogram, the fibula is still markedly displaced posteriorly and seems still to be securely lodged behind the flare of the tibia.

FIG. 3-A

FIG. 3-B

After second manipulation.

Anatomical reduction of the fibula with no widening of the ankle mortise. Again, the plaque of bone from the medial portion of the medial malleolus is noted, indicating that the deltoid ligament was ruptured in this case from the proximal insertion rather than from the talus.

with the foot in external rotation, and an oblique fracture of the fibula below the tibiofibular ligaments, as well as rupture of the deltoid ligament, the medial malleolus remaining intact. The unusual displacement was not recognized.

Two hours after injury, under pentothal sodium and nitrous oxide anaesthesia, manipulation was carried out by traction on the ankle, internal rotation of the heel, and compression of the ankle. Roentgenograms (Figs. 2-A and 2-B) showed clearly that the fibular shaft was still markedly displaced posteriorly and medially, and that the ankle mortise was still wide. Clinically, a sulcus was present at the usual site of the distal portion of the fibular shaft.

Bosworth's article was called to mind; in fact, we had been looking for this type of fracture since 1947.

The fingers were placed behind the fibular shaft, which could be indistinctly palpated behind the tibia, and a strong pull was applied. After ten seconds of pulling, a loud crunching noise was heard; additional pull

was applied, and suddenly the fibular shaft snapped loudly back into anatomical position (Fig. 3-B).

After six weeks of immobilization in a toe-to-groin cast, a short skin-tight walker was used for four additional weeks. The patient soon returned to his job of delivering bread and, when last seen seven months after injury, had a normal range of motion, normal roentgenograms, and was asymptomatic except for the usual mild pain with weather changes.

It can be seen from Figures 2-A, 2-B, 3-A, and 3-B that for reduction to occur the proximal fragment had to pass from behind, over the posterolateral tibial prominence, to its normal position. In the usual external-rotation fracture, the main mass of the inferior tibiofibular ligaments holds the fibular shaft snugly against the tibia, thus supplying the fixation required for the usual fracture of the malleolus. In most cases, the anterior inferior tibiofibular ligament, with or without a fragment from the lateral aspect of the tibia, is avulsed by the force displacing the distal fragment of the fibula. In this unusual fracture-dislocation, it seems necessary to assume either that the main tibiofibular ligaments (the interosseous portion) are somewhat lax or that the posterolateral tibial protuberance is somewhat smaller than usual, allowing the proximal fibular fragment to rotate around the tibia. It is clear that the main tibiofibular ligaments are intact for, if they were ruptured (along with a varying length of the interosseous membrane), there would be nothing to hold the fibular shaft so securely in its posteromedial position. In our case it was easily determined by clinical examination after reduction that the ligaments were intact.

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DISCUSSION

Developmental Deformities of the Lower Extremities

(*Continued from page 527*)

of the normal? Is the primary disturbance, when there is one, vascular, neurological, ligamentous, or muscular? Is it inherent in the gene, due to an early metabolic change in the embryo, a mechanical factor *in utero*, a hormonal imbalance, or what? What is primary and what is secondary? May I point out again that the relaxations are nearly always general, affecting the ligaments and muscles of the trunk and the upper extremities as well as the lower. This is something which is often not observed.

Dr. I. William Nachlas, Baltimore, Maryland: Medial torsion of the lower extremities may appear to be unimportant in these days of extensive hip reconstructions, intramedullary nailings, and replacements of femoral heads by metallic prostheses, but it has real significance, both diagnostic and functional. Many of you will recall that patients with these deformities were sent to us for treatment as rachitics. In the clinic of Dr. Edward A. Park, where careful clinical studies, x-ray examinations, and even pathological-section evaluations were used as the criteria for diagnosing rickets, it soon became evident that, in spite of the deformities of their limbs, these patients did not have rickets. Their malformations constituted a separate and distinct clinical entity, one that could not be cured by the administration of vitamin D. The evolutionary origin of this condition was suggested by a survey of many newborn infants, in 80 per cent. of whom one could find some medial torsion. Postnatal malposture as described by Dr. Kite and Dr. Knight may exaggerate the deformity, but why do the children find this particular posture one that is natural for them?

Functionally, medial torsion also has significance. If the deformity persists, the patient has one of two alternatives: (1) He can propel himself with his feet turned in, but, by doing so, he loses the efficiency of the push-off that the forward-facing foot gives; or (2) he can externally rotate his limb at the hip and abduct the foot at the mid-tarsal joint. The mechanical deficiencies of these compensations are obvious.

The *laissez faire* treatment that has just been reported as being successful in one case is unfortunately not uniformly successful. If it were, we should not find medial torsion in adults. We have approved methods of treatment for permanent twists, which vary from manipulative procedures through braces and casts to rotation osteotomies. Fortunately the milder treatments are generally successful in the young infant. In the small percentage of patients who do not respond to these procedures, more radical manoeuvres can be performed at a later date.

GIANT OSTEOID OSTEOMA

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Eleven unusual and microscopically characteristic benign tumors have been encountered in a comprehensive study of pathological specimens in approximately 2,000 cases of primary tumor of bone at the Mayo Clinic. This tumor, which apparently always originates within bone, consists principally of partially calcified osteoid trabeculae in a vascular stroma. The literature on benign tumor of bone is already abundant and confused, but this lesion seems distinctive enough to merit record and comment. We have chosen to call the tumor under discussion "giant osteoid osteoma" because this name seems most fitting. It is distinctively different from the ordinary osteoid osteoma and should not be classed with it, as will be evident from the following discussion.

LOCATION

In our series of eleven tumors, four involved part of the following vertebrae: the third thoracic, eleventh thoracic, third lumbar, and fifth lumbar. In each of these a portion of the vertebral arch was destroyed and in three the vertebral body itself was affected. Five tumors were found in long bones: two in the femur, two in the tibia, and one in the humerus. Various parts of the diaphysis of these long bones were involved. Of the two remaining tumors in the series, one was in the upper fourth of the patella and the other had almost completely destroyed the talus.

PATHOLOGICAL FEATURES

All eleven tumors involved the cancellous or medullary portion of the bone and caused erosion, often in an eccentric fashion, of the cortex in the area of the tumor. The tumors, except for those affecting vertebrae, about which exact information was lacking, were contained by the occasionally bulging periosteum. The exact size of the neoplasms could not always be determined accurately, since they were usually removed piecemeal. This was true especially in the cases in which the vertebrae were involved. A notable fact, however, was that the tumors were large, in contrast to the familiar osteoid osteoma. Those found in the extremities varied from 2.5 to more than five centimeters in diameter. The tumor which affected the talus scarcely extended beyond the confines of the bone and the periosteum was intact. A lesion microscopically identical to this one had affected only the upper fourth of the patella, although the patient had experienced pain in that region for four years. The five tumors located in the long bones were associated with considerable thickening of the adjacent cortex, similar to that observed in an ordinary osteoma. This cortical thickening was produced by the growth of new subperiosteal as well as endosteal bone.

Grossly, the lesions were homogeneously hemorrhagic, friable, and granular, varying from a reddish color to purple. The bleeding at operation was often impressive. The specimens are granular and gritty because of the calcifying osteoid which they contain. The tumors were reasonably well demarcated from the surrounding normal or sclerotic bone.

Microscopic examination of many sections from all lesions revealed the following features:

1. Osteoid tissue showing varying, usually slight, degrees of calcification was the

* The Mayo Foundation is a part of the Graduate School of the University of Minnesota.

most prominent feature. It was characteristically disposed in a fairly regular pattern unlike that of osteogenic sarcoma. In parts of two tumors, however, this osteoid pattern closely simulated that observed in fairly well differentiated osteogenic sarcomata. In general, the trabeculae were distinctly broader, longer, and more widely separated than those of the usual osteoid osteoma.

2. Vascularity was the next most prominent feature. The spaces between the osteoid trabeculae were filled predominantly by dilated capillaries, or, on occasion, by blood-filled spaces without recognizable walls. The vessels were thin-walled and usually did not have a muscular component.

Although fibrous tissue containing benign spindle-shaped nuclei was present in some tumors, it was not predominant in any and was minimal in most. Multinucleated benign giant cells in variable numbers were observed in all tumors. They lay in the scanty connective tissue between the osteoid trabeculae and the blood channels or, in some instances, appeared to be within the blood-filled spaces. The giant cells were, on the average, smaller and contained fewer nuclei than those of benign giant-cell tumors.

Evidence of malignancy was absent in all cells. Benign osteoblasts were prominent around the osteoid trabeculae. Mature fibroblasts made up the rather insignificant spindle-cell component of these tumors, and only small amounts of collagen were observed. The giant cells did not show evidence of malignancy.

CLINICAL FEATURES

The youngest patient in the group was five years of age when he was first seen at the Clinic; his symptoms had been present for about six months. On the other hand, the oldest of the eleven was sixty years of age when first seen. The remainder of the patients ranged in age from sixteen to thirty-one years. There were ten males and one female.

The symptoms of this group of patients did not differ markedly from those of any other group of comparable size with benign osseous tumors. Pain was the cardinal symptom and was most often described as nagging, boring, or like a toothache in quality. In all cases in which the examining physician specifically asked, it was found that the pain was more troublesome at night than during the day. All patients complained of pain in the region involved, and with few exceptions the pain was centered directly over the affected part. In one case, however, the pain from a lesion of the mid-portion of the tibia was referred to the foot and ankle of the affected leg. In another case pain from a lesion of the trochanter was referred to the knee of the same limb. The duration of the pain varied from three weeks to five years. The average duration was 25.8 months.

Five of the eleven patients had swelling or a definite mass associated with the pain. Of the remaining six patients, four had involvement of the vertebrae, one had invasion of the upper third of the femur, and one had involvement of the tibia. In all but the last mentioned, it would have been difficult for the patient to discern a mass unless it had been large. Three of the patients complained of a limp on the affected weight-bearing extremity; two had mentioned intermittent swelling of an adjacent joint, and two had demonstrable weakness of the involved extremity. Four patients lost weight; one of these lost a total of forty pounds (18.1 kilograms). One patient attributed his weight loss to anorexia resulting from continual pain. The two most common symptoms were pain and swelling.

Physical examination revealed the most frequent finding to be swelling or a firm mass, which was present in six cases. Tenderness to palpation was noted in only five patients, and three of these did not have palpable tumors. Atrophy of adjacent muscles was noted in three cases, and five patients had limited motion of adjacent joints. Of these five, the spinal columns of three, the knee of one, and the ankle of one were involved. A patient with spastic paraplegia had a definite sensory level at the third thoracic interspace, due to encroachment of the tumor on the spinal cord at that level. Increased heat was present in the region of the tumor in two cases.

On the basis of the clinical findings, including roentgenograms and the history, the two most common diagnoses made preoperatively were osteomyelitis and osseous tumor. In one particularly baffling case, in which the lumbar portion of the spinal column was affected, the diagnosis was narrowed down to a choice between postpoliomyelitic syndrome and a lesion of the lumbosacral plexus. In another case the initial diagnosis was destructive arthritis of the ankle. In three cases the lesions were definitely considered to be of inflammatory origin, and in five they were believed to be neoplastic. Three patients had been advised elsewhere to have amputation performed and one of these had had a specimen removed for biopsy. Only one patient in the group of eleven had received definitive therapy elsewhere before his visit to the Clinic; the treatment had consisted in drilling of the bone at the site of the lesion on three occasions.

The results of routine laboratory studies offered the clinician little help in making the initial diagnosis. In two cases only were any of the findings abnormal, and in both instances it was the rate of sedimentation. The rate in one case was twenty-five millimeters in one hour, and in the other seventy-six millimeters in one hour (Westergren method). One patient had 11,600 leukocytes per cubic millimeter of blood and two others had low-grade albuminuria. The cerebrospinal fluid of the four patients whose vertebrae were involved did not show abnormal variations.

The initial roentgenograms revealed definite evidence of lesions of bone in all but one instance, and in this case the roentgenograms subsequently showed evidence of a lesion. It is impossible to outline a definite set of criteria for diagnosis of this type of benign lesion of bone on the basis of the roentgenograms. The roentgenograms for five patients were interpreted as showing evidence of destruction of bone only, and it is of note that three patients whose vertebrae were involved were in this group. The roentgenograms of each of the five patients having a lesion in a long bone showed an area of bony sclerosis and in each a central area of bony rarefaction was seen. Osteomyelitis of long duration was the most common diagnosis in this group. In the eleventh case the roentgenogram was interpreted as showing evidence of an osteoma arising from the third lumbar vertebra. In all cases, the roentgenograms were most significant in delineating a lesion as a variant from the normal. Thus, decisive action in the form of biopsy could be taken to ascertain definitely the nature of the lesion and its proper treatment.

After biopsy, ten patients underwent operation for removal of a neoplastic mass. The lesion of one of these was located in the transverse process and lamina of the third thoracic vertebra, so that complete removal could not be accomplished. Nevertheless, wide laminectomy to relieve the extrinsic pressure on the thoracic portion of the spinal cord, followed by five courses of roentgen therapy, served to eradicate the symptoms. In another case, in which the upper third of the femur was involved, it was necessary to perform curettage of the area twice before permanent relief was obtained. The eleventh patient underwent amputation at the junction of the upper and middle thirds of the femur after biopsy and an erroneous diagnosis of sarcoma. Five patients were given a course of roentgen therapy after operation. Only one course was administered to each of four patients; the fifth patient, already mentioned, received five courses because of the inaccessibility of the tumor and the surgeon's knowledge that he had not removed all of the abnormal tissue.

The postoperative course of these patients indicated the benign nature of the lesions. The three patients most recently treated were well or improved at follow-up intervals of twelve months, fourteen months, and thirty months respectively. The other patients have remained well for periods varying from 4.3 to eighteen years.

Detailed reports of the eleven cases follow.

REPORT OF CASES

CASE 1. A seventeen-year-old white male registered at the Clinic on June 24, 1952. He had had pain, swelling, and tenderness in the region of the right ankle joint since injuring it three years previously. He

walked with a marked limp and was wearing a short double-iron brace on his leg. There was 75 per cent. loss of motion in the right ankle joint with exquisite tenderness, moderate swelling, and increased local heat.

Laboratory findings were non-contributory. A roentgenogram (Fig. 1-A) revealed a destructive lesion of the talus with some extra-osseous formation. Before biopsy of the lesion, a needle with a large bore was inserted and blood could be withdrawn at will from different areas of the tumor. An arteriogram demonstrated marked vascularity of the tumor, one large artery entering the central portion of the lesion. On July 2, 1952, a tourniquet was placed above the lesion which was resected after fresh frozen sections revealed its benign nature. So much of the body and neck of the talus were destroyed by the tumor that it was necessary to follow resection with a modified triple arthrodesis; bone from the bone bank was used to fill the defect created. When the patient returned in June 1953, the result was good except for a draining sinus in the area.

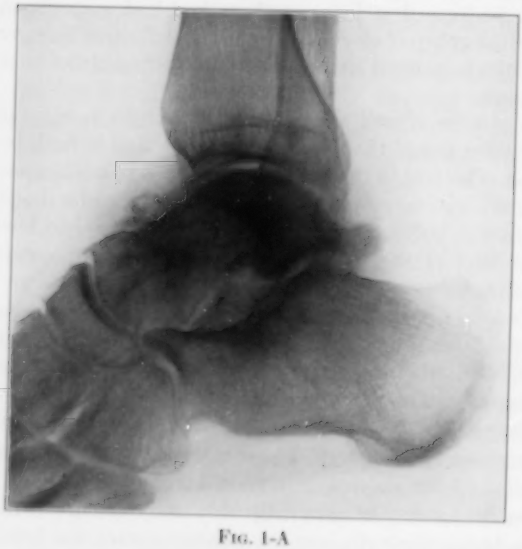

FIG. 1-A

The specimen consisted of thirty-two grams of homogeneous granular, fairly soft, friable bloody fragments (Fig. 1-B). Sections could be prepared readily from this material without decalcification, although osteoid was the predominant element throughout (Fig. 1-C).

It seemed, on pathological examination, that the lesion was identical to the osteogenic fibromata described by Lichtenstein [4] who made the comment that "when such tumors are comparatively small, it may be difficult to distinguish them clearly from osteoid

FIG. 1-B

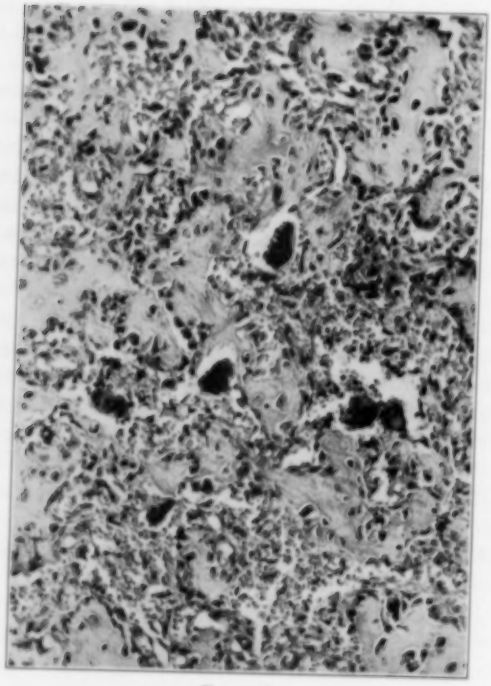

FIG. 1-C

Fig. 1-A: Case 1. The roentgenogram showed a destructive lesion of the talus. At operation it was found that most of the talus had been replaced by tumor tissue.

Fig. 1-B: Showing the gross specimen from the same lesion. The tissue was granular, friable, and hemorrhagic.

Fig. 1-C: Photomicrograph (× 170, hematoxylin and eosin stain) showing rather coarse osteoid trabeculae separated by thin-walled vascular channels and a few benign giant cells. The entire lesion showed the same pattern.

osteomas". This case focused our attention on similar cases in our files in which lesions had been tentatively labeled "osteogenic fibromata", a name which seems much less fitting than that of "giant osteoid osteoma" which we are proposing.

CASE 2. A twenty-year-old white man registered on January 11, 1946, complaining of pain in the right leg at the distal end of the tibia of more than four years' duration. He had had "drilling" operations performed elsewhere in 1942, 1943, and 1945, which brought only temporary relief. The progress of the lesion from September 1, 1943, to January 17, 1946, is illustrated in Figures 2-A and 2-B. The pain awakened the patient at night and he was taking 200 to 300 grains of acetylsalicylic acid (twenty to thirty aspirin tablets) every twenty-four hours for relief. The roentgenogram made on his admission was interpreted as showing evidence of old osteomyelitis of the middle third of the right tibia.

On January 24, 1946, the anterior half of the mid-portion of the tibia and the lesion were excised (Fig. 2-C). A bone graft from the ilium was used to fill the defect. When last heard from in July 1952, the patient was in good health and had not suffered a recurrence of the tumor.

The pathologist's diagnosis was "atypical hemorrhagic so-called osteoid osteoma, 5 by 2.5 by 2.5 centimeters, invading cortex and medulla".

The gross features of this tissue were exactly like those in Case 1 and microscopic sections (Fig. 2-D) revealed a pattern like that in Case 1. Again the osteoid component was the most striking. Small thin-walled vessels were abundant and relatively small foci of spindle cells were present. It is interesting that, although the tumor itself was just like that in the preceding case, there was no surrounding bony sclerosis in Case 1.

CASE 3. A white man, twenty-three years old, had injured his left thigh one year before registration on December 13, 1944. He had had severe pain and moderate swelling in the lower thigh area for four months. He had lost thirty-nine pounds (17.7 kilograms) in six months. He was found to have an ill-defined tumefaction involving the anterolateral aspect of the distal end of the left femur with increased local heat and effusion

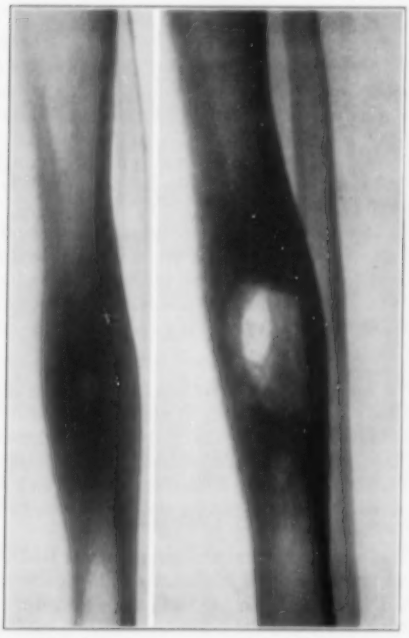

FIG. 2-A

FIG. 2-B

FIG. 2-C

Fig. 2-A: Case 2. Roentgenogram of the left tibia made on September 1, 1943, showing a radiolucent area surrounded by dense sclerotic bone.

Fig. 2-B: Roentgenogram made on January 17, 1946. Note the marked progression of the process.

Fig. 2-C: The tumor was removed together with the anterior half of the tibia. (Figs. 2-A through 2-C reproduced by permission of J. B. Lippincott Company from M. B. Dockerty, R. K. Ghormley, and A. E. Jackson: Osteoid Osteoma. A Clinicopathologic Study of 20 Cases. *Annals of Surgery*, **133**: 85, 1951.)

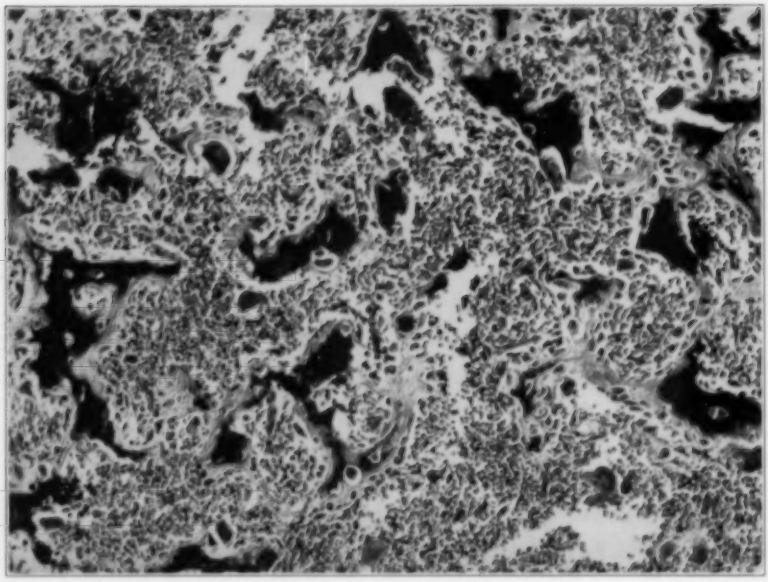

FIG. 2-D

Photomicrograph (× 150, hematoxylin and eosin stain) of a section from the tumor, consisting of partly calcified osteoid trabeculae again separated by numerous thin-walled vessels and an occasional giant cell.

into the knee joint. The erythrocyte sedimentation rate was seventy-six millimeters in one hour (Westergren method), but results of other laboratory tests were essentially normal. Marked thickening of the cortex of the distal half of the femur was noted (Fig. 3-A). Some medullary destruction could be seen which was most suggestive of chronic osteomyelitis, but the presence of a malignant tumor could not be ruled out. Effusion was present in the knee joint.

The diagnosis, after biopsy of material from the rarefied portion, was osteogenic sarcoma. Accordingly the left lower extremity was amputated at the base of the greater trochanter on December 18, 1944. When last heard from, on April 4, 1949, the patient was in good health.

The gross specimen revealed marked thickening of the cortex of the femur in the region indicated in the roentgenogram. This thickening was due to deposition of sclerotic benign bone in the medulla as well as in the subperiosteal region (Fig. 3-B). The central rarefied portion was filled by a soft granular tumor which involved the medulla and cortex on one side and produced moderate bulging of the periosteum. It measured 3.2 by 2.5 by 2 centimeters. This soft, friable material was well demarcated from the surrounding bone and was microscopically the same as in Cases 1 and 2 (Fig. 3-C).

CASE 4. A white man, thirty-one years old, registered on January 10, 1951. He had had increasing pain and swelling of the right knee for four years. At the onset the pain occurred only at night. A preoperative diagnosis of internal derangement of the right knee was made and exploration was carried out elsewhere in June 1947, but no abnormality was found. Examination at the Clinic revealed the circumference of the right knee to be 1.5 centimeters greater than that of the left. There was moderate limitation of flexion and the patella was enlarged. An osteolytic lesion involved the proximal third of the patella, the superior border of which appeared to be fuzzy (Fig. 4-A).

Patellectomy was performed on January 15, 1951. The initial pathological impression was that the lesion represented an atypical giant-cell tumor. It measured two centimeters in diameter and its gross and microscopic features were identical to those of tumors described in the preceding cases. He returned three months after the operation, having obtained an "excellent result". When last heard from, in July 1953, he did not mention any complaints referable to his knee.

This tumor was less remarkable for its size than for the fact that none of the surrounding sclerosis usually associated with an osteoid osteoma was present. Also, as seen in Figure 4-B, the osteoid trabeculae formed a distinctly looser meshwork than that observed in the ordinary osteoid osteoma.

CASE 5. A nineteen-year-old white man registered at the Clinic on May 25, 1934, complaining of a dull

FIG. 3-A

FIG. 3-B

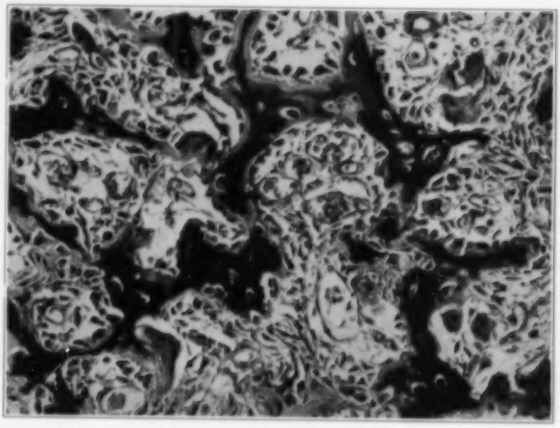

FIG. 3-C

Fig. 3-A: Case 3. On the roentgenogram the tumor, which measured 3.2 by 2.5 centimeters, was largely obscured by the associated sclerosis.

Fig. 3-B: Photomicrograph (× 95, hematoxylin and eosin stain), showing non-neoplastic subperiosteal new bone adjacent to the tumor.

Fig. 3-C: Photomicrograph (× 175, hematoxylin and eosin stain) showing characteristic pattern from the same tumor.

aching pain in the right leg of four years' duration; the pain became worse at night. For one year there had been swelling below the right knee. Examination disclosed a firm tumor-like mass affecting the upper third of the right tibia. The roentgenograms have been discarded, but had been interpreted to show "localized" osteosclerosis involving a portion of the upper third of the shaft of the right tibia with central irregular areas of rarefaction. The process was believed to be chronic osteomyelitis, but the possibility of malignant tumor was not excluded.

At operation on May 28, 1934, the greatly thickened cortex was found to be almost perforated posteriorly by a mass of soft bluish-red or purple material in a central cavity. This was thoroughly curetted out. A routine culture of this material was negative. Because the pathologist considered the lesion to be a giant-cell tumor of a low grade of malignancy, postoperative roentgen therapy was given to the affected bone. When last heard from, in June 1953, the patient was in good health and had not had any further difficulty with the leg.

The tumor was delivered to the pathologist in pieces which aggregated five centimeters in diameter. In all respects it was similar to the tumors in the previous cases, except that some of the fragments were grittier because of calcification of some of the osteoid trabeculae (Fig. 5).

CASE 6. A white man, sixty years of age, registered at the Clinic on February 21, 1921, having had pain in the left arm for one year. The pain was worse when he was idle and was also worse at night. Three weeks before he registered, an osteopath had told him he had a tumor. On examination, tender swelling of the

FIG. 4-A

Fig. 4-A: Case 4. Roentgenogram showing a lesion which involved the upper third of the patella.

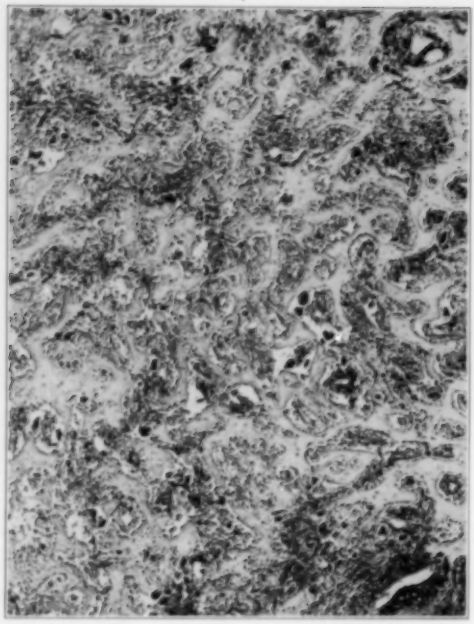

FIG. 4-B

Fig. 4-B: Low-power photomicrograph (× 30, hematoxylin and eosin stain) showing the characteristic pattern. The interlacing osteoid trabeculae are only slightly calcified.

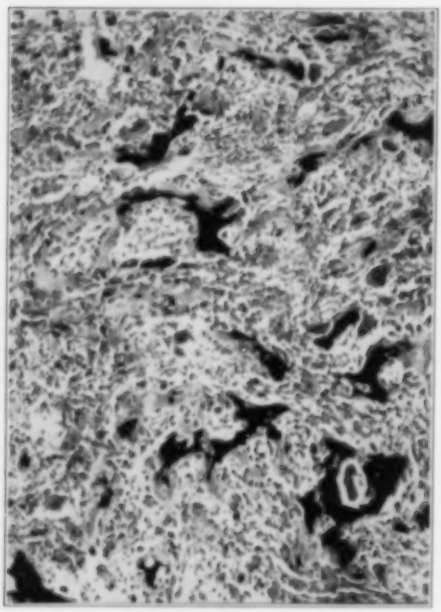

FIG. 5

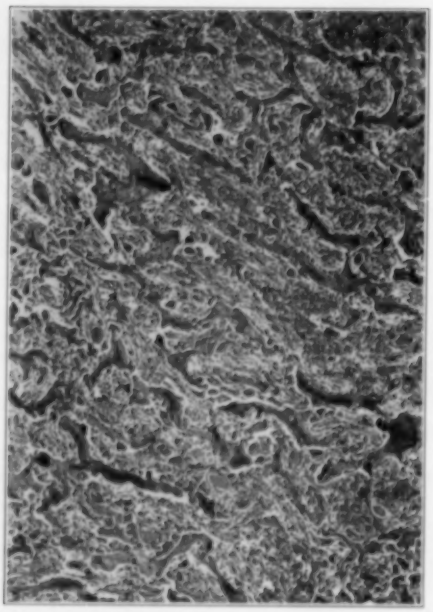

FIG. 6

Fig. 5: Case 5. Photomicrograph (× 90, hematoxylin and eosin stain) of a specimen in which the osteoid was fairly heavily calcified in some sections.

Fig. 6: Case 6. The photomicrograph (× 50, hematoxylin and eosin stain) showing the same loose pattern of osteoid trabeculae so commonly seen in these lesions. Some fibroblasts, as well as vessels, are present between the osteoid beams.

FIG. 7-A

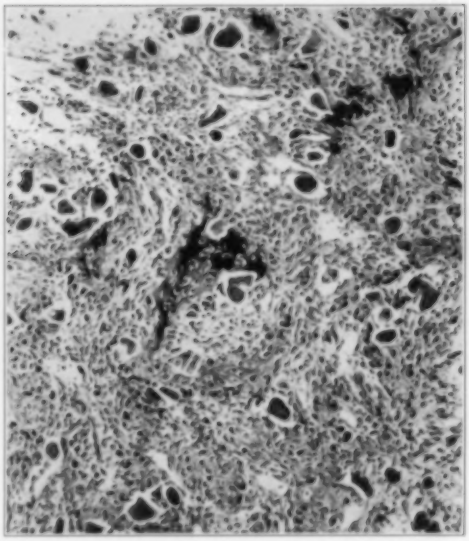

FIG. 7-B

Fig. 7-A: Case 7. The roentgenogram revealed a subperiosteal lesion in the femur.

Fig. 7-B: Photomicrograph (× 95, hematoxylin and eosin stain) showing the same basic pattern as was seen in the other lesions. Fairly numerous benign giant cells are present.

middle portion of the left humerus was found. The roentgenograms, since discarded, were interpreted as showing sarcoma of the middle third of the humerus. The contents of a central rarefied region in the humerus were removed on February 25, 1921. A diagnosis of osteoma containing foreign-body giant cells was made. The patient was given radium and roentgen therapy postoperatively. He died after prostatic resection ten years later, without suffering further trouble with his arm.

The tissue removed from the humerus was granular, rather firm, friable, and bloody. It was in fragments aggregating 3.5 centimeters in diameter. The same fundamental pathological features observed in all the cases previously described were present (Fig. 6).

CASE 7. A white man, eighteen years of age, registered at the Clinic on October 10, 1922, complaining of pain in the left hip and thigh, of five months' duration. The pain had increased in severity until drugs were required for sleep. Tenderness was present on pressure over the upper part of the left femur. A roentgenogram was interpreted as showing osteomyelitis in the upper third of the femur with marked periosteal overgrowth (Fig. 7-A).

On October 13, 1922, the rarefied region was unroofed. The surgeon encountered a soft mass. The material, preserved in formalin, has the gross features noted in the preceding cases and aggregates 2.5 centimeters in diameter. The pathologist's diagnosis was benign giant-cell tumor.

The pain recurred in January 1923, and the patient returned to the Clinic on July 23, 1923. The area was re-explored on July 25, 1923, and a layer of bone an eighth of an inch thick was encountered covering a cavity filled with "granulations". The preserved material obtained from this operation consists in somewhat friable, fairly firm, granular tissue. Roentgen-ray therapy was used postoperatively. When last heard from, in 1936, the patient was in good health and had not suffered any further recurrence.

The original clinical diagnosis in this case had been subperiosteal hematoma. The microscopic studies do not show the orderly trabeculae of osteoid ordinarily observed in heterotopic ossification, the pattern being instead that of a disorderly meaningless osteoid framework so characteristic of all these lesions (Fig. 7-B). In addition, careful questioning did not uncover a history of trauma, nor was any systemic disease which might lead to subperiosteal hemorrhage recognized. Even stronger evidence against this lesion being a hematoma was the fact that all the symptoms recurred after its incomplete removal.

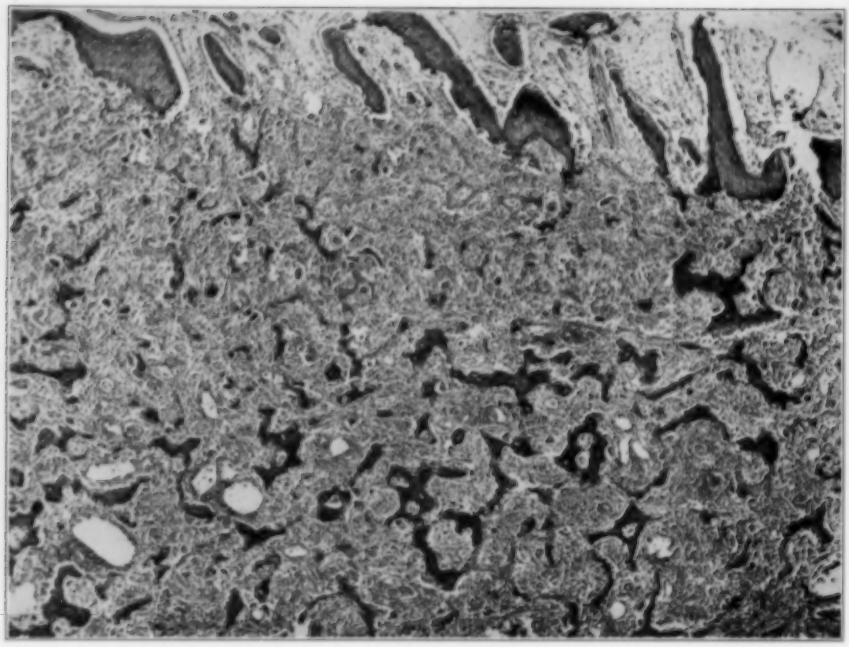

FIG. 8

Case 8. Photomicrograph (× 45, hematoxylin and eosin stain) showing the discrete edge of the lesion in the area where it borders on normal cancellous bone.

CASE 8. A sixteen-year-old white boy registered on August 31, 1927, complaining of gradually increasing pain in the small of the back for the previous two and a half years and aggravated by exertion. He had lost a "considerable" amount of weight during the previous year. Muscle spasm occurred on the left side, and the right side of the upper lumbar region was tender to pressure. There was equivocal evidence of compression of the spinal cord and moderate scoliosis. A roentgenogram, no longer available for review, revealed a fairly large osteoma arising from the third lumbar vertebra on the right side. The tumor was removed "entirely" on September 7, 1927, by "cracking it off" and by curettage. It was found to involve the right transverse process, the adjacent lamina, pedicle, and part of the vertebral body. Curettage was continued until "solid bone was encountered". The pathologist's diagnosis was foreign-body giant-cell tumor.

The patient was given two roentgen-ray treatments postoperatively. He experienced immediate relief and, when last heard from fourteen years later, he stated that he was in perfect health.

The preserved specimen consists of a circumscribed, granular, somewhat friable mass in pieces which aggregated more than four centimeters in diameter. Parts of the tumor were moderately sclerotic.

The gross and microscopic features of this tumor make it fall logically into the group being described. Some parts of the osteoid were moderately calcified, probably accounting for the roentgenographic diagnosis of osteoma. Ordinary osteoid osteomata also show varying degrees of calcification and hence show varying degrees of density in the roentgenograms. The surgeon noted in this case that the underlying cancellous bone of the vertebral body was denser than the tumor itself (Fig. 8).

CASE 9. A twenty-year-old white man came to the Clinic on February 25, 1935. He had had dull aching of increasing severity under the left scapula for eighteen months. For six months he had noted progressive sensory disturbances in the lower extremities. Examination revealed that, in addition to motor and sensory disturbances below the level of the third thoracic vertebra, he had a complete block of the cerebrospinal fluid.

A roentgenogram (Fig. 9-A) showed irregular destruction involving the lamina and left transverse process of the third thoracic vertebra with small areas of increased density. An irregular mass involved the left side of the lamina of the third thoracic vertebra.

FIG. 9-A

Fig. 9-A: Case 9. The x-ray showed destruction and some calcification of parts of the third thoracic vertebra.

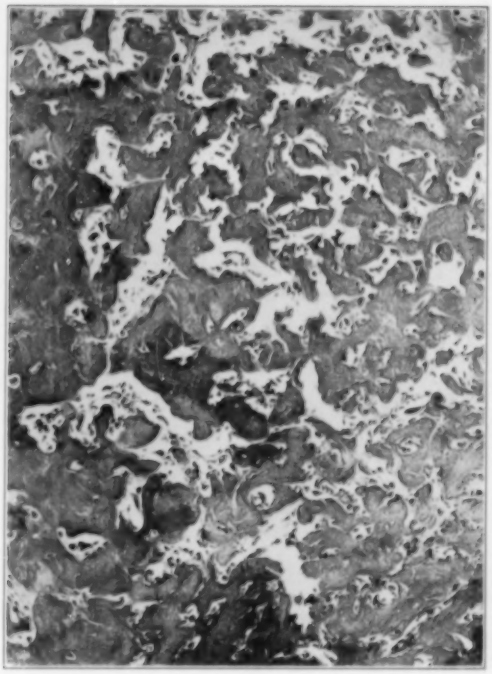

FIG. 9-B

Fig. 9-B: A sclerotic portion (× 125, hematoxylin and eosin stain) from the lesion, showing calcified osteoid trabeculae closely packed. Such areas were observed in parts of two tumors.

At surgical exploration on March 4, 1935, a mass was found between the spinous processes of the third and fourth thoracic vertebrae. The vertebral body was involved and the spinal cord was compressed. Subtotal excision of the tumor was accomplished. Because of a diagnosis of osteosarcoma, postoperative roentgen-ray therapy was administered. The patient returned on several occasions during the next three and one-half years and was in excellent condition when last seen. He stated in a follow-up letter, in March 1949, that his health was good.

The specimen, which aggregated 3.5 centimeters in diameter, was composed of partially calcified, irregular, firm masses. The histological appearance, except for somewhat more patchy calcification, was characteristic of this group of cases (Fig. 9-B).

CASE 10. A boy, five years of age, was registered at the Clinic on January 15, 1951. He had been limping for three months. Examination revealed slight weakness and decreased deep reflexes of the left lower extremity. Roentgenographic studies of the lumbar portion of the spinal column and pelvis did not reveal any pathological condition. A definite diagnosis was not made at this time. When he returned in August of the same year he had the additional complaint of pain low in the back after walking and he could not run. In addition to the signs previously noted, tenderness was present on pressure over the lower lumbar portion of the spinal column.

A roentgenogram (Fig. 10-A) showed evidence of a destructive process in the fifth lumbar vertebra which might be either inflammatory or neoplastic.

At operation on August 30, 1951, a friable, soft, spongy mass was found to be replacing and bulging from the left portion of the body and the adjacent lateral mass and facet of the fifth lumbar vertebra. This was partially removed. When the patient was last heard from, in October 1952, his condition was good. The parents stated that all his symptoms were disappearing.

The specimen consisted of slightly calcified, bloody, friable fragments, aggregating two centimeters in diameter. The microscopic sections showed again the predominance of osteoid trabeculae which were fairly broad in places (Fig. 10-B). Again the trabeculae were separated by vascular fibrous tissue containing occasional foreign-body giant cells.

CASE 11. A white woman, twenty-four years of age, came to the Clinic on February 17, 1944, having had pain in the lower portion of the back with occasional attacks in the left lower quadrant of the abdomen

FIG. 10-A

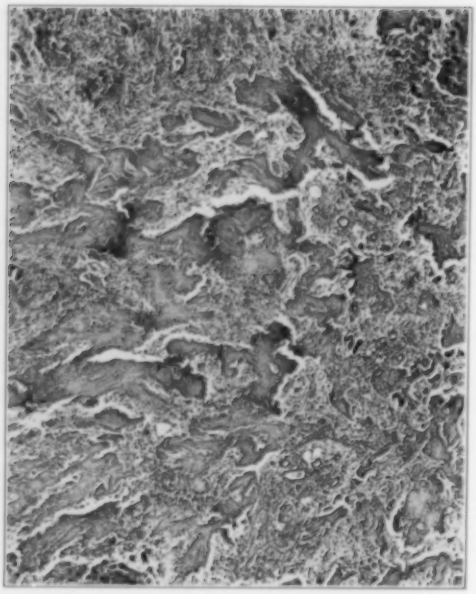

FIG. 10-B

Fig. 10-A: Case 10. The roentgenogram revealed a destructive process in the fifth lumbar vertebra and its left pedicle.

Fig. 10-B: Photomicrograph (× 40, hematoxylin and eosin stain). The osteoid trabeculae were fairly broad in parts of this tumor. A fibrous-tissue component may be seen separating these trabeculae.

for one year. Physical examination was non-contributory. A roentgenogram showed that the left pedicle of the eleventh thoracic vertebra was indistinct (Fig. 11-A). Laminectomy was performed on April 20, 1944, and a tumor was found bulging from and destroying the pedicle of the vertebra. The tumor was completely removed. It was granular and somewhat fibrous and the fragments aggregated two centimeters in diameter. The same basic pattern was observed histologically (Fig. 11-B). When last heard from, in February 1951, she stated that she was not having any trouble.

COMMENT

It is readily apparent that these tumors bear similarities to several other lesions. Osteoid osteoma, in our opinion, is the lesion they mimic most closely from the histological standpoint. In five cases this resemblance was increased by the thickening and osteosclerosis surrounding the lesion. In fact, in one case the tumor had been reported previously to be an unusually large osteoid osteoma.[1] In other reported series of osteoid osteomata, for example, Sherman's Case 1, examples of the type of tumor we are describing have been included. Several features serve to distinguish our tumors from ordinary osteoid osteoma. Among these are the much greater size, more marked vascularity, more orderly pattern of larger osteoid trabeculae, tendency to erode through the cortex, and the inconstancy of the surrounding bony sclerosis in the cases under discussion. Grossly these tumors have been softer and more hemorrhagic than the usual osteoid osteoma. These lesions may be basically osteoid osteomata, but they represent a special type lacking the biological properties of restricted growth and the non-aggressiveness usually observed. It should be emphasized that in our cases all the lesions showing sclerosis in surrounding areas were large. Histologically, they were the same as those without sclerosis.

Aneurysmal bone cysts as described in detail by Lichtenstein [3] bear similarity to the lesions in our cases. He stated that in some areas surrounding these cysts osteoid prolifera-

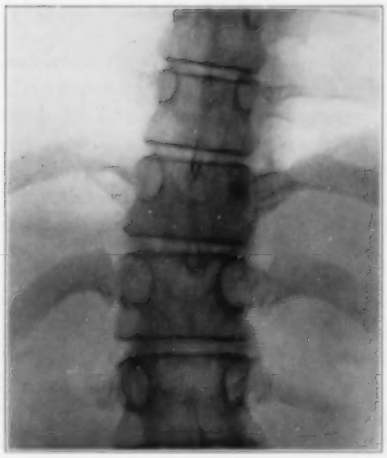

FIG. 11-A

Fig. 11-A: Case 11. In the roentgenogram, the left pedicle of the eleventh thoracic vertebra was indistinct.

Fig. 11-B: Photomicrograph (× 70, hematoxylin and eosin stain) showing a characteristic pattern from the same tumor.

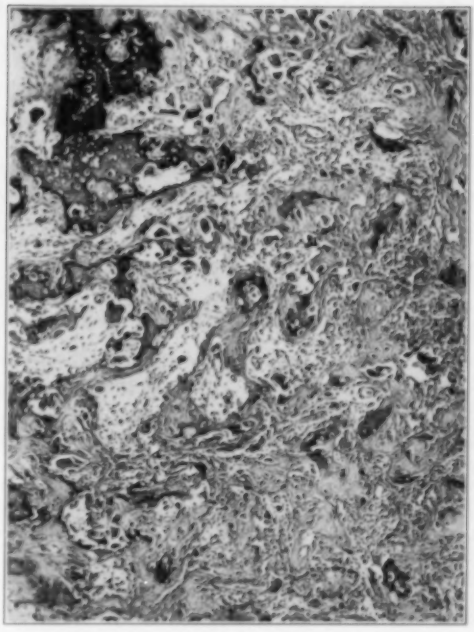

FIG. 11-B

tion may be prominent, and the vascular stroma described in his cases is reminiscent of that in ours. In none of these cases, however, were there discrete cavernous vascular channels and blood pools of the type he depicted and described as "showing the essential cavernous character of the lesion". Our own experience with aneurysmal bone cyst convinces us that it is distinctly different from the tumor under discussion. Microscopic sections from many areas in all eleven tumors revealed the proliferating osteoid tissue to be uniformly the most prominent component. In addition, pain was a much more significant clinical feature in cases of giant osteoid osteomata than in those of aneurysmal bone cysts.

Osteogenic fibroma of bone, another tumor discussed by Lichtenstein [4], seems, from his description, to contain all the elements found in the tumors which we studied. If the lesions are identical, we are of the opinion that the term "osteogenic fibroma" is an unfortunate one, because the fibromatoid component is the least striking histopathological feature.

Giant-cell tumor of bone is another tumor which may be confused with giant osteoid osteomata. In fact, in a discussion of primary giant-cell tumors of the vertebrae, Lewis, in 1924, included some cases which were almost certainly like those we are describing. It is probable that some of the atypical lesions or "variants" of giant-cell tumor mentioned in other publications are examples of the tumor which we call "giant osteoid osteoma", although inadequate histological descriptions have made it impossible to verify this point. In any event the tumors in our cases are distinctly different from giant-cell tumors. The prominent, plump spindle-cell stroma of giant-cell tumors is lacking. The sites of predilection are different for the two types of tumors, giant osteoid osteomata occurring in any part of the bone. Finally, of course, the osteoid proliferation predominant in our cases is distinctly unlike the pattern of giant-cell tumor.

Hemangioma may be considered a likely diagnosis for lesions such as these, but we

feel that the osteoid proliferation overshadows the vascularity and makes it of secondary importance.

The curability of these lesions, when treated by adequate curettage with or without subsequent irradiation therapy, attests to their benign behavior. One might ask whether they are in fact true neoplasms. The clinical course reported in these cases indicated that the lesions progressed in size until therapy was instituted. It is possible that these tumors are merely a reaction to some sort of injury or alteration in physiology, but this is pure conjecture. One can forestall the chance of an erroneous diagnosis of osteogenic sarcomata by merely insisting on cytological evidence of malignancy before making such a diagnosis.

SUMMARY AND CONCLUSIONS

We have discussed the pathological and clinical features in eleven examples of a distinctive type of benign tumor of bone. These tumors are characterized by a prominent network of osteoid trabeculae showing varying degrees of calcification and a vascular stroma which fairly frequently contains benign giant cells and little fibrous tissue. Because of their histological features we feel that they most closely resemble osteoid osteomata. Their biological behavior indicates a distinct difference from this lesion, however, and we suggest the designation "giant osteoid osteoma".

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DISCUSSION

Epiphyseodesis

(*Continued from page 555*)

With the three pegs inserted in tripedal fashion, the epiphyseal plate is well bridged. In the 250 cases which we have already reported there have been two failures; both occurred because the surgeon made the fenestration too far distally so that his pegs did not cross the epiphyseal line. These, of course, were obvious technical failures. There has been one case in which the pegs were absorbed. The reason for this was not clear to us; fractures may have occurred when the pegs were removed. Except for this case union occurred in all of these hips within three months and in some within two months. The process may be summarized as follows: healing takes place over a period of about eight weeks; the epiphyseal plate fuses, which requires about twelve weeks; and finally the epiphyseal line is completely obliterated and the pegs are incorporated.

One other minor advantage of this method is that the pegs are visible in the roentgenograms, and we know where they have been placed. With very high operative standards, there has been no case of aseptic necrosis. This was surprising, because we had feared that there might be occasional aseptic necrosis. I realize, as Dr. McCarroll suggested, that if an inexperienced surgeon operated upon a hip, handled his instrument carelessly, and gouged out a large amount from the capital epiphysis, or if he went through the articular surface of the head into the acetabulum, damage could be done and aseptic necrosis could be expected. I have heard a number of reports of aseptic necrosis after use of the nail, and I know that I am not always able to

(*Continued on page 654*)

STRESS FRACTURES OF THE PUBIC RAMUS

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The occurrence of stress fractures at sites such as the metatarsals and tibiae in personnel of military installations has been reported frequently, but literature regarding stress fractures of the inferior pubic ramus has been very sparse [1,2,3,4]. These fractures have been reported, however, by military physicians who have had the opportunity to observe recruits undergoing rigorous infantry training.

FIG. 1-A

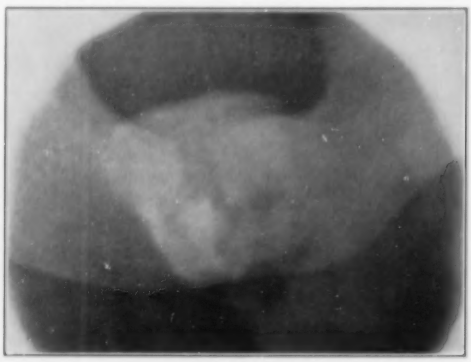

FIG. 1-B

FIG. 1-C

Case 1. Stress fracture of the right inferior pubic arch.

Fig. 1-A: Roentgenogram showing irregular break in the right inferior pubic arch and moderate calcification.

Fig. 1-B: Roentgenogram made two weeks later shows increase in calcification.

Fig. 1-C: Roentgenogram made four weeks after Fig. 1-A.

The precipitating factor is undoubtedly the unusual physical activity in a formerly sedentary individual. The condition is probably the result of unusual pull and strain of the adductors and the hamstring muscle groups with an associated adductor pull, more anteriorly, on the inferior pubic ramus. The recruits first notice pain in the inguinal, perineal, and adductor regions, bilaterally, with tenderness on palpation of the inferior pubic ramus.

Clinical examination reveals moderate to severe pain in the region of the ischial tuberosity and inferior ramus of the pubis. Pain is aggravated by all motion which places stress on this area. As a result of this condition, the patient walks with a definite limp. During examination, moderate to deep pressure about the inferior pubic ramus is required to elicit the pain, which differentiates the condition from a bursitis in this area. The pain in a stress fracture usually persists, diminishing gradually, for a period of four to six weeks, while pain in the traumatic fracture of the same region disappears in one to two weeks.

Roentgenographic findings reveal a definite break in the continuity of the cortex. It is an irregular break in a vertical direction through both cortices, and there is calcification of a moderate degree surrounding the area. As healing progresses, the fracture fissure gradually diminishes and the calcification increases.

It is important to bear this condition in mind as it may help to avoid making a mistaken diagnosis of benign or malignant tumor and unnecessary surgical exploration.

CASE REPORTS

Case 1: A twenty-year-old white male, who had poor muscular development and a past history of little participation in sports or other activities requiring physical exertion, complained of pain in the right groin and perineal area after he had completed four weeks of infantry basic training. The pain had become progressively severe and was aggravated by marching and exercises.

Physical examination revealed tenderness on deep palpation of the right inferior pubic arch and ischial tuberosity area, which was accentuated by motion in all quadrants and which was most marked in flexion, adduction, and external rotation. A marked limp was noted with increased stress on the hamstring groups. Roentgenograms revealed a fracture of the inferior pubic arch with callus formation (Fig. 1-A). The patient walked with crutches for a period of four weeks and then used a cane for two weeks, with gradual disappearance of pain and limp.

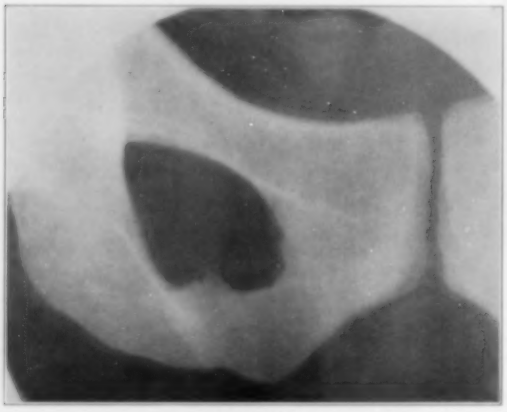

Fig. 2-A

Case 2: A white male, twenty-one years old, of asthenic build and poor muscular development had a history of sedentary daily occupations; he engaged in no sports activity and in only minimal walking or physical exertion. He complained of pain in the right perineum and groin for one week after having completed five weeks of infantry basic training. There was no history of direct or indirect trauma. A limp began one week after symptoms occurred.

Physical examination revealed tenderness about the ischial tuberosity and the inferior ramus of the pubis, aggravated by all types of motion in these regions. When the hip was put into flexion, abduction, and external rotation, pain was elicited.

Roentgenograms revealed a fracture of the right inferior pubic arch (Fig. 2-A).

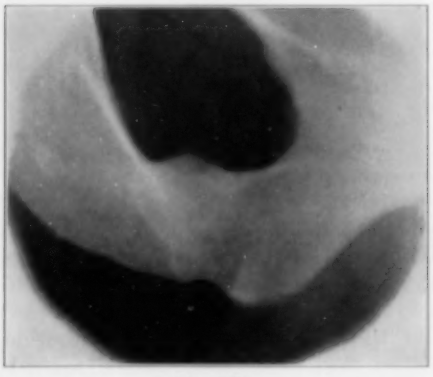

Fig. 2-B

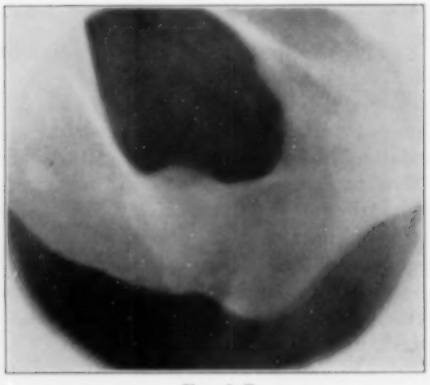

Fig. 2-C

Case 2. Stress fracture of the right inferior pubic arch.

Fig. 2-A: Initial roentgenogram of fracture. Fig. 2-B: Roentgenograms made three weeks later.
Fig. 2-C: Roentgenogram made five weeks after Fig. 2-A.

FIG. 3

FIG. 4-A

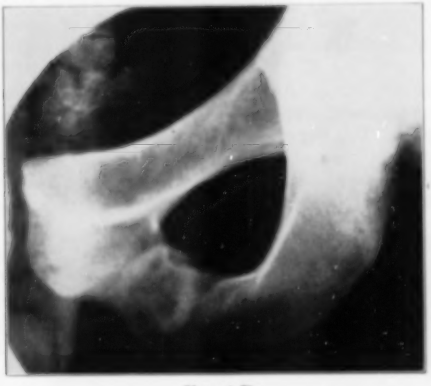

FIG. 4-B

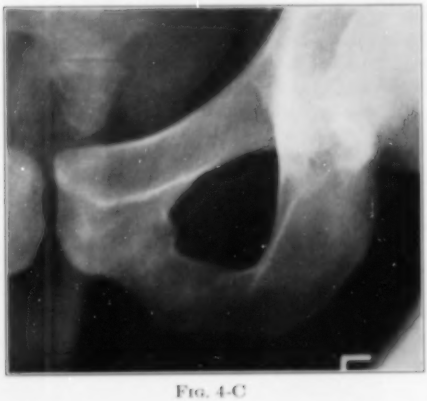

FIG. 4-C

Fig. 3: Case 3. Stress fracture of the right inferior pubic arch.
Fig. 4-A: Case 4. Roentgenogram shows fracture of the left inferior pubic arch.
Fig. 4-B: Three weeks later, the callus formation is sharply visible.
Fig. 4-C: Roentgenogram after five weeks showed the fracture to be well healed.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 5. This initial roentgenogram shows a stress fracture of the right inferior pubic arch.
Fig. 5-B: Roentgenogram made four weeks later.

The patient was assigned to limited duty, and there was gradual diminution of pain with healing at the fracture site. The man used crutches for thirteen weeks and then a cane for three weeks more.

CASE 3: A white male, twenty-one years old, was seen nine weeks after induction into military service; he first noticed pain after six weeks of training. It began after he had spent considerable periods of time on his feet, marching, running, or walking, during basic training. In civilian life he had had a sedentary position as a machinist; he had never participated in sports or other physical activities and had never done much walking.

Physical examination revealed severe pain in the perineal area, and he walked with a limp. Roentgenograms revealed a fracture of the inferior pubic arch (Fig. 3). The patient was allowed to walk, without weight-bearing. He used crutches for four weeks, when the pain had diminished and there was roentgenographic evidence of adequate callus formation at the fracture site.

CASE 4: A twenty-year-old white male noticed pain in the left groin after two and one-half months of basic training. It was first noted in the morning after a day of moderate muscular activity. The pain in the left perineum was aggravated by walking, running, and marching double-time. In civilian life he had had a sedentary occupation as a tractor mechanic. He had not participated in sports or in any activities requiring unusual physical exertion prior to entering military service.

Physical examination revealed moderately severe pain in the left perineum; the patient walked with a limp. Roentgenograms revealed a fracture of the left inferior pubic arch (Fig. 4-A). The use of crutches without weight-bearing for five weeks gradually brought diminution and subsidence of the pain and the limp.

CASE 5: A white male, twenty-two years old, was gradually aware of increasing pain in the right perineal area after two and one-half months of basic training. This began gradually, but it increased to such a degree that walking or any other type of activity requiring the use of the lower extremities was very difficult. A moderate limp developed and the patient was placed on crutches. In civilian life the patient had been a bellboy and had done only light work. He had never participated in any sports and did very little walking or other exercises.

During the physical examination, deep pressure elicited severe pain in the right perineal area. The patient walked with a limp. Stress on the hamstring and adductor muscles caused pain. Roentgenograms revealed march fracture of the right inferior pubic arch (Figs. 5-A and 5-B). After four weeks on crutches without weight-bearing, the pain and limp had disappeared.

SUMMARY

The diagnosis of march fracture of the inferior pubic arch should be considered whenever there is a history of unusual physical stress associated with complaints of pain in the perineum; roentgenographic evidence of a break in the continuity of the inferior pubic ramus and calcification about the site confirm the diagnosis.

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FRACTURE HEALING AFTER FIXATION WITH STANDARD PLATES CONTACT SPLINTS, AND MEDULLARY NAILS

An Experimental Study *

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During recent years, when we have wished to apply internal fixation to the fragments of a transverse or short oblique fracture of the shaft of a long bone, we have used an Eggers plate[1] (internal contact splint) or a medullary nail; we have largely abandoned the use of the standard bone plate and of the dual plates.

The occurrence of delayed union in fractures of long bones treated by open reduction and internal fixation by means of a slotted (Eggers) plate, in several patients at about the same time, caused us to wonder whether or not there was any advantage in this method of fixation. When these patients were re-operated upon for bone-grafting, the plates were found to be solidly fixed by callus and connective tissues which had grown up through the slot and around the screws. It seemed likely that this had occurred fairly early in the healing phase of the fracture. The fragments were thus fixed to the plates and in this way any compression factor which may have been present was eliminated; moreover, in instances in which absorption had occurred, the fragments were held apart

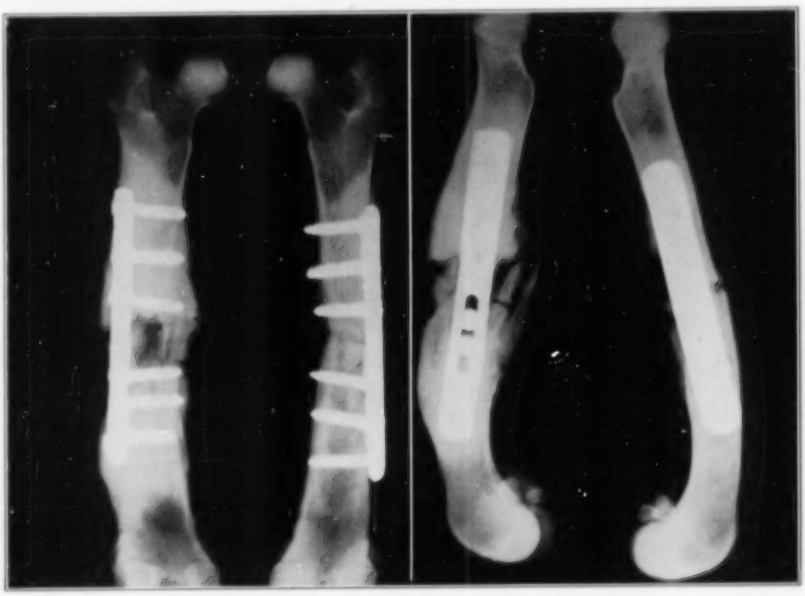

FIG. 1-A FIG. 1-B

Roentgenograms made nine weeks after application of a slotted plate on the left femur and a standard plate on the right femur. Infection was present on the side fixed with a slotted plate. New bone had partly covered the plate and solidly fixed it to the fragments, so that they could not slide together and close the gap which had resulted from non-union and infection. Union of the fracture was progressing satisfactorily on the non-infected side, to which the standard plate had been applied.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 29, 1953.

FIG. 2-A FIG. 2-B

Roentgenograms made nine weeks after application of a slotted plate on the left side and an intramedullary nail of the Lottes type on the right. The fracture on the right had been created too low and fixation was not adequate. Non-union and shortening with excessive callus resulted, while on the side treated with a slotted plate union progressed in a satisfactory manner.

(Figs. 1-A and 1-B). In addition we felt that, with the extremity immobilized in a cast without function, muscle tone would be lessened and would, therefore, not produce a very strong compressing force, and that function and even weight-bearing would have to be carried out early in the postoperative period in order to cause sliding together of the fragments on the plate. Consequently, we have asked ourselves: What is the most efficient form of internal fixation now available for the treatment of fracture of a long bone?

An answer to this question might be obtained from a clinical study in which a sufficiently large series of reasonably similar fractures were treated in rotation by each one of what we consider the best methods. We felt, however, that there would be so many variables that, even at the end of such a study, a true picture would be hard to obtain. Experimental material was more readily available; and it was believed that a more accurate comparison of the rate of healing, as well as of the incidence of complications, could be obtained in the laboratory than by clinical observations, although some of the conditions found to exist in the experimental animal might not be transposable to the human patient. Consequently, we have made a comparative study of fracture healing in which standard plates, slotted plates, and the intramedullary nail were used in an effort to determine which is the most efficient method.

It was demonstrated by one of us[6] that bony union occurred more rapidly following an arthrodesis of the knee in which positive pressure was applied; such pressure was obtained by turnbuckles fastened to pins which were inserted transversely through the tibia and the femur, the turnbuckles being tightened from time to time. We have wondered whether the unusually rapid union was caused by the positive pressure, more perfect immobilization and apposition, or a combination of these factors.

Charnley and Baker demonstrated that positive pressure affects not only the rate but also the character of union between two surfaces of cancellous bone. In biopsy speci-

FIG. 3-A FIG. 3-B

Roentgenographic appearance thirteen weeks after plating of the left femur and fixation of the right femur with an intramedullary nail. Adequate fixation was provided by the nail and union of the fracture was a little more advanced on that side, although both fractures showed solid union clinically after removal of the fixation devices.

mens from patients operated upon for knee fusion they found that, with pressure of about twenty-five pounds per square inch, union was more rapid and the amount of callus very small. However, this has not been shown to be true of cortical bone.

Eggers, Shindley, and Pomerat carried out experiments using the parietal bones of rats, in which pressure was obtained by rubber bands, and concluded that pressure stimulated union of these surgical fractures. They also believed that the amount of pressure must not be too little or union would not occur, and that it should not be excessive or non-union and necrosis of the bone surface would result. On the other hand, Ford, Lottes, and Key carried out an experiment using the ilium of dogs in which rib grafts were sprung into drill holes in the ilium, pressure being produced by the tension on the rib. These workers failed to find evidence that pressure accelerated union, as there was little difference between the group to which pressure had been applied and the group treated without pressure.

More recently Friedenberg and French applied pressure to a surgical fracture of the ulna of dogs. They used a spring applied across the fracture site and held in place by an intramedullary wire. They found that pressures of from twelve to eighteen pounds resulted in union of the fracture, while with pressure of less than this amount or with pressure considerably greater (thirty to thirty-five pounds) the fragments failed to unite. This experiment was not ideal in that the circulation of the distal fragment may have been disturbed and the distal fragment, being detached, was deprived of function. Furthermore, the control side lacked adequate immobilization, so that it could not be ascertained whether union was stimulated by pressure or by better fixation. However, the failure of union in the group in which high pressure was used suggests that the response of cortical bone to pressure is different from that of cancellous bone.

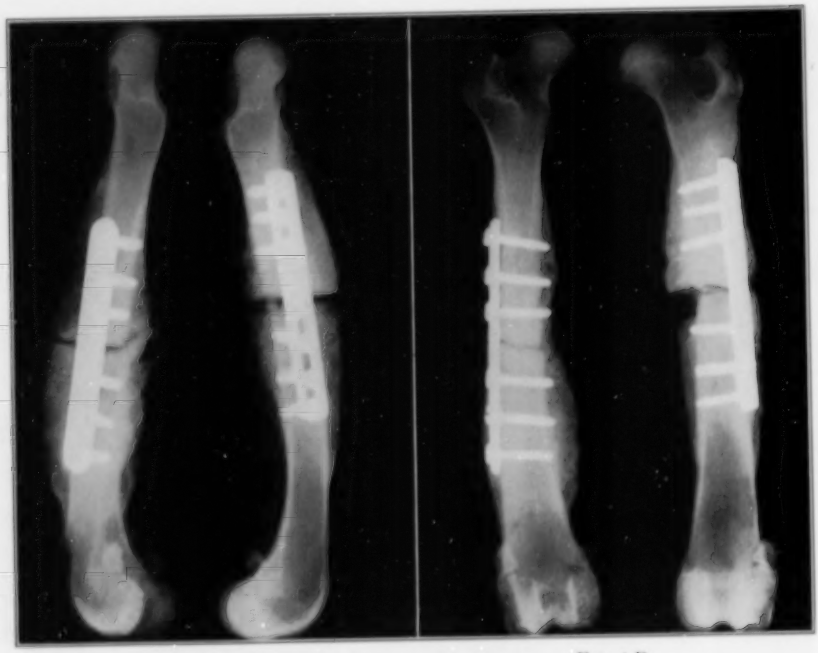

FIG. 4-A FIG. 4-B

Figs. 4-A and 4-B: Roentgenographic appearance of specimens eight weeks after plating; mild infection was present on both sides. Marked new-bone formation about the end of each fragment was associated with absorption at the fracture line and non-union on both sides. There was evidence of shortening on the side treated with a slotted plate, but the gap at the fracture site was about the same as that on the side treated with a standard plate.

FIG. 5-A FIG. 5-B

Figs. 5-A and 5-B: Roentgenograms of specimens removed fourteen weeks after operation. The wounds were clean and no infection was present. The side treated with a slotted plate appeared solid clinically. However, the side treated with a nail revealed non-union with motion in all directions about the nail and, as demonstrated in the x-ray, there had been marked terminal erosion and shortening.

It is well known that, when the continuity of a bone is disrupted so that a fracture results, an irregularly defined area about the damaged ends of the bone dies. Reduction of the fracture then results in dead bone being placed against dead bone. During the process of repair of the fracture this devitalized bone is absorbed and is replaced by living bone. This is accomplished both by terminal erosion and by creeping substitution. It has been reasoned that any type of fixation of the fracture which rigidly holds the fragments

in the position obtained at the time of reduction will allow a gap to form as this zone of dead bone is absorbed. The fracture fragments are then held apart and there may be delayed union or non-union. In order to provide a method of internal fixation of fractures which would prevent the fracture fragments from being held apart during this period of absorption, Eggers devised the slotted plate or contact splint which, if properly applied, would allow the fragments to slide together as absorption took place and eventually bring living bone into contact with living bone; in addition the process of union would be stimulated by pressure exerted on the fracture site by muscle pull. If it is true that union of the fractured fragments can occur only after the zone of devitalized bone has been absorbed, fixation by means of a rigid plate should result in a high incidence of non-union. We have felt that union of a fracture occurs through bridging of the fracture area by callus, so that union by bone may occur about the fracture, while reconstruction and remodeling continue for a long time after clinically solid union has been established. Furthermore, if the fragments are fixed in such a way that they may slide together as absorption occurs, one would expect shortening to occur. Eggers did not find evidence of shortening in experimental fractures fixed with the slotted plate when union occurred in a normal manner.

In order to compare the healing of fractures treated by application of the Eggers plate with fractures treated by a standard plate and with fractures treated by an intramedullary nail, it was necessary to study two groups of experimental animals. In the first group surgically created fractures of the shafts of both femora in dogs were fixed with an Eggers plate on one side and with a standard plate on the other. These animals were sacrificed at intervals and the femora were studied in order to determine the progress of union. In the second group, similar surgical fractures in the shafts of femora were created in dogs; on one side the fragments were fixed with an Eggers plate and on the other with an intramedullary nail of the Lottes type (Figs. 3-A and 3-B). These animals were also sacrificed at intervals after the operation and the femora were removed and studied. The findings in the first group of animals have been reported elsewhere,[7] but, in order that the study may be as complete as possible, it is necessary that the results of the first study be included in this paper.

MATERIALS AND METHODS

Forty adult dogs were used and these were divided into two groups. They were operated upon under aseptic conditions, general anaesthesia being used. In the first group of nineteen dogs, one femur was exposed and divided transversely in the middle third with a Gigli saw; the fracture was reduced as accurately as possible; and the fragments were fixed with a standard steel plate with six screws. (As some of the standard plates bent, extra heavy plates were made and these were used on the last nine dogs.) The wound was closed with silk. The other femur was then operated upon in a similar manner and fixed with a stainless-steel Eggers plate with six screws. Here, the self-tapping stainless-steel screws were first tightened and then backed out one full turn until the fragments could be pulled apart and pushed together without difficulty. The fragments were then pushed together and the wound was closed and covered with a collodion dressing.

In the second group of twenty-one dogs, similar osteotomies of the femora were performed. The left femur was fixed with an Eggers plate and the opposite femur with a medullary nail. A heavy-cored, three-flanged nail, one-fourth inch in diameter, of the Lottes type was used. These nails were six inches long and were, therefore, cut off when medium-sized dogs were used. No external fixation was used and in a relatively short time most of the animals were moving about quite well, as the internal fixation which we used was strong enough to support full weight-bearing.

At intervals of from seven to sixteen weeks the animals were sacrificed by lethal anaesthesia and the femora were removed and examined in the gross and by x-ray. After

TABLE I

SUMMARY OF RESULTS IN THE OSTEOSYNTHESES OF THIRTY DOGS

Time (*Weeks*)	Group I: Standard Plate Bony Union	Group I: Standard Plate Infection	Group I: Eggers Plate Bony Union	Group I: Eggers Plate Infection	Group II: Eggers Plate Bony Union	Group II: Eggers Plate Infection	Group II: Medullary Nail Bony Union	Group II: Medullary Nail Infection
7	−		−		− −	+	− −	+
8	− −	+	+ −	+				
9	+ +		+ −	+	− −	+	− −	+
10	+ − −		+ − +		+ −	+	+	+
11	+ + −	+	+ + −					
12	+		+		− −	+ +	− −	+ +
13	+		+		+ +		+ −	
14	+		+		+ + − −		− − − +	+ +
16	+		+		−	+	−	
Total	9 + 6 −	2 +	10 + 5 −	2 +	5 + 10 −	6 +	3 + 11 −	7 +

Each plus sign indicates one femur united; each minus sign indicates one femur in which union did not occur.

the plate or nail had been removed, the bone was tested to determine whether the union was by bone or by fibrous tissue. The bones were then fixed in formalin, decalcified, and split longitudinally in order to observe the condition of the medullary canal and fracture site. Blocks which included the fracture site were removed and prepared for microscopic study.

OBSERVATIONS

Because of severe infection, loss, or death, or from other causes, only fifteen animals in each group were available for study at the end of seven weeks or longer after the operation. The results of the treatment of the sixty osteotomized femora in these animals are recorded in Table I.

Gross Examination

As is noted in Table I, granuloma or infection was present about the fracture site in seventeen of the sixty femora. This occurred in spite of our efforts to prevent operative infection and in spite of antibiotic therapy in Group II. In all of these the wounds were well healed, and there was no pus. Cultures were not made, but granulation tissue was present around the fracture, so that we have classed these as cases of infection. However, some of them may represent an inflammatory change as a result of motion and a foreign body at the fracture site. Study of the microscopic sections of these specimens did not reveal evidence of infection in most cases, although a few showed definite evidence of infection. In no instance in which this reaction was present did union by bone occur, although in many such instances a considerable amount of new bone had formed around the end of each fragment. All animals with infection or granuloma, therefore, were unfit for comparative study.

On comparison of the standard with the Eggers plate, bony union was not found to be present on either side in the seven-week or eight-week specimens. Bony union was present on both sides in one of the nine-week animals; in the other, bony union was present only on the side treated with the standard plate, while on the side treated with the Eggers plate the wound was infected (Figs. 1-A and 1-B). Of three animals sacrificed at ten weeks, two had union on both sides and one had union on the side treated with the standard plate but not on the side treated with the Eggers plate, in which a granuloma was present.

Of the three animals in this group sacrificed at eleven weeks, the screws had pulled out in one and the femur was deformed, but both sides were united by bone. In one of the others, infection and fibrous union was present on the side treated with the standard plate, while bony union was present on the side treated with the Eggers plate. In the third animal only fibrous union was present on each side.

In the animals sacrificed at twelve, thirteen, fourteen, and sixteen weeks, union by bone was present on both sides and there was little difference between them. It was our impression that in the animals sacrificed before the eleven-week interval, union, either by fibrous tissue or by bone, was slightly more advanced on the side treated with the Eggers plate.

In the second group of animals, in which the Eggers plate is compared with the medullary nail, the incidence of infection or granuloma and non-union was unusually high. This was partly because, in order to accommodate the six-inch nail, unusually large dogs were selected and, while the nails appeared to fix the femora solidly when inserted, after about three or four weeks the dogs began to limp and did not use the limb treated with the nail. At autopsy it was found that in these the relatively small (quarter-inch) nail was loose in the medullary canal, and that the fragments could be moved to and fro as well as rotated upon one another (Figs. 2-A and 2-B). Where fixation was inadequate and false motion was present, the callus was apt to be excessive. In the later experiments in this group, smaller dogs were used and the nails were cut off to fit the shorter femora. In this second group there were six infections on the side treated with the plate and seven on the side treated with the nail, leaving only six dogs for comparative study. Of these, five of the femora on the side treated with the Eggers plate were solid and only three on the side treated with the nail were united by bone. There thus appears to be an advantage in favor of the slotted plate. However, it was our impression that, when the fragments were firmly fixed by the nail and no infection was present, union was almost the same on both sides (Figs. 3-A and 3-B).

Roentgenographic Examination

The presence or absence of union by bone as revealed by study of the roentgenograms agreed quite well with the findings noted on gross examination, except that the roentgenographic evidence tended to lag slightly behind the clinical evidence of union, since in two of the earlier specimens which had clinically solid union, bony union did not appear to be present in the roentgenogram. The x-rays also revealed differences in the firmness of union which were not detected on gross examination and, in four instances in the first series in which union was present on both sides, it appeared to be slightly more firm on the side treated with the Eggers plate than it was on the side treated with the standard plate. Where infection or false motion was present, the x-ray revealed the new bone around the ends of the fragments, as well as the absorption and failure of union (Figs. 4-A and 4-B). In most of the cases either with or without infection in which union failed to occur on the side treated with a slotted plate or a nail, the femur was shortened and the callus was excessive (Figs. 5-A and 5-B).

Microscopic Examination

Since no specimens were obtained less than seven weeks after the operation, the early phases of the healing of fractures of long bones will not be considered in this report. In almost all of the specimens there was the usual collar of new subperiosteal cancellous bone near the end of each fragment adjacent to the fracture; in this area the marrow canal was filled with cancellous bone, except in the specimens with medullary nailing in which the nail prevented the full development of the endosteal callus.

In the earlier specimens (eight to eleven weeks) the external callus was quite large and consisted of connective tissue, cartilage, and cancellous bone. In specimens removed

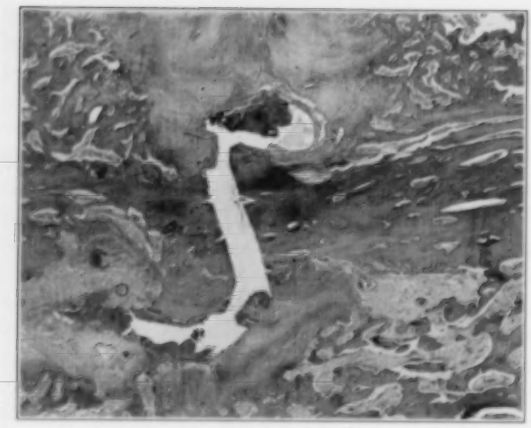

Fig. 6: Low-power photomicrograph of one cortex of a specimen removed nine weeks after operation. The devitalized ends of the fragments projected into a cystic cavity which appeared to be the result of a hematoma. There was no evidence of change along the cut surfaces, although extensive absorption and remodeling was taking place on either side and union was being secured by connective tissue, callus, and cancellous bone on both the periosteal and endosteal surfaces. There was no infection and this fracture was solid clinically.

Fig. 7: Low-power photomicrograph of a specimen removed at ten weeks, in which there was a low-grade wound infection, showing extensive erosion of the cortex.

FIG. 6

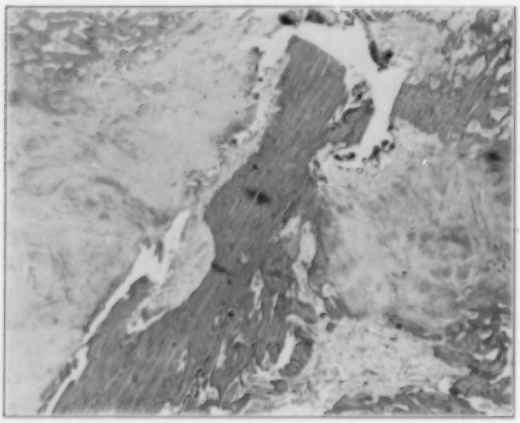

FIG. 7

twelve weeks or more after the operation the external callus was smaller and consisted of more robust cancellous bone, while the connective tissue and cartilage had largely disappeared from the periosteal callus, from the area between the ends of the fragments, and from the medullary canals. These were filled with robust cancellous bone which united the two fragments. In the fractures fixed by a medullary nail which was large enough to fix the fragments firmly, the external callus tended to be smaller than in similar fractures fixed by plates.

In some of the earlier specimens cystlike cavities occupied the fracture site, sometimes extending entirely across it and surrounding the devitalized ends of the fragments. In these, union might not be present or might be effected by a massive external callus. The cavities contained some amorphous precipitate and apparently were the remains of old hematomata. When the end of a fragment projected into such a cavity and its surface was not covered by soft tissue, it remained inert and showed no evidence of absorption (Fig. 6).

Ordinarily, however, the ends of the fragments were covered with soft tissue, newly formed appositional bone, and trabeculae which fused the cortices. They also presented evidence of absorption by osteoclasts and vascular connective tissue. This was not a gradual eating away of the devitalized end of the bone such as would tend to shorten it and, by removing the devitalized portion, bring the living bone ends into contact, but an extensive reconstruction of the bone ends which tended to convert the compact bone into a coarse cancellous structure. This was effected by irregular erosion of the subperiosteal and medullary surfaces and of the walls of the vascular canals in the bone. In those cases in which the end of the fragment was covered with vascular connective tissues, terminal erosion was present; this sometimes was quite extensive if infection was present (Fig. 7).

In the fractures which were uniting, the formation of new appositional bone was the most striking feature. In the earlier specimens the bone ends were united by delicate trabeculae which sprang from the periosteal and endosteal callus and from the appositional

FIG. 8

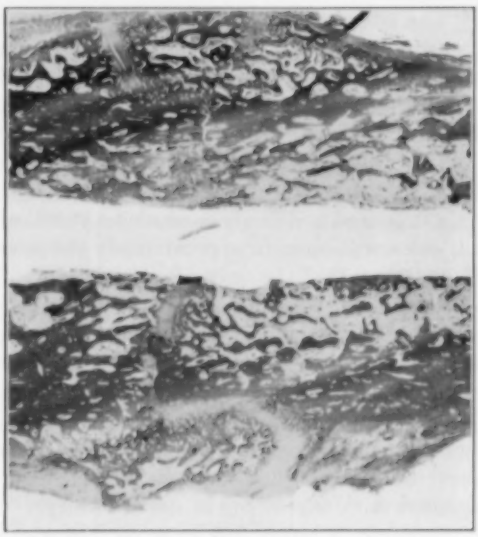

FIG. 9

Fig. 8: Low-power photomicrograph of a specimen removed thirteen weeks after fixation with a slotted plate. Fusion by external callus was seen with remodeling and early union of the cortices by new-bone trabeculae.

Fig. 9: Low-power photomicrograph of specimen removed thirteen weeks after fixation with an intramedullary nail. Fusion by external callus had taken place and there was advanced reconstruction and union of the fracture. Note the nail tract in the medullary canal.

bone which covered the devitalized ends of the fragments. This appositional new bone appears to be formed in membrane and to arise from the periosteal and endosteal surfaces, creeping along and covering the surface of each fragment. Trabeculae spring from its surface and may fuse with similar trabeculae from the opposite fragment, or they may adhere to this fragment and thus unite the two. The appositional bone appears to cover and to adhere to or fuse with either living or devitalized bone. In the later specimens the trabeculae were more robust and the periosteal callus was less extensive (Fig. 8). The medullary canal was filled with newly formed cancellous bone which also united the two fragments.

The microscopic picture as described above was seen in fractures fixed by the standard plate, the Eggers plate, or the medullary nail. Unless the section included the part of the nail tract which traversed the canal and lessened the medullary callus (Fig. 9), it was not possible to determine the method of fixation by microscopic examination. In no instance were the fragments seen to be in actual contact in the microscopic sections, but in many sections they were closely approximated and this seemed to favor early fusion by appositional bone.

DISCUSSION

Gross, roentgenographic, and microscopic examinations of the specimens revealed very similar findings. In both Group I and Group II, results seemed to be somewhat better with the contact splint. This was more marked in comparison with the medullary nail than in comparison with the standard plate.

It is believed that the reasons for this are that: First, it was possible to get closer approximation of the fracture at the time of surgery by impaction of the fracture after the plate had been applied; second, the slotted plate by test as well as in practice is stronger than the standard plate and provides better fixation; and third, continued approximation of the fragments undoubtedly occurred upon weight-bearing on the side treated with the slotted plate during the first few weeks.

The advantage of the contact splint over the intramedullary nail as seen in these experiments reflects directly on the factor of immobilization. In the animals in which the nail was tight enough to provide adequate immobilization, there was a slight advantage on the nail side, but, where this was not true, non-union always developed on the side treated with the nail, while the side treated with the plate united.

It is believed that approximation and continued immobilization of the bone ends, rather than pressure by itself, are the important factors and that, if the fragments are firmly impacted and firmly fixed with a standard plate, slotted plate, or an intramedullary nail, union will occur in approximately the same time.

It is true that the devitalized ends of the fragments do not grow together and tend to be absorbed; when union occurs, this is usually accomplished by new periosteal and endosteal bone and is accompanied by erosion from within; in this way both the living and the devitalized bone are gradually reconstructed and replaced by new bone which tends eventually to form bone structure in accordance with Wolff's law. Some of the devitalized bone may remain as part of the original bone structure or it may be incorporated in the new bone and persist long after the fracture has healed. We saw no evidence which led us to believe that fracture healing is accompanied by a gradual eating away of the ends of the fragments with telescoping of the extremity.

However, if union fails to occur, the ends of the fragments may undergo rapid absorption and may be held apart by the standard plate as absorption occurs, whereas the Eggers plate or the medullary nail should permit the fragments to slide together and close the gap. In some of our specimens in which infection and non-union occurred on the side treated either with the Eggers plate or with the medullary nail, the ends of the fragments were absorbed and the bone was shortened. In such instances the fragments fixed with the nail always were in closer contact than those fixed by either of the plates. We have observed clinically and experimentally that, if the Eggers plate had been in place for a few weeks (two weeks or longer), unless it had been loosened by infection, it was firmly fixed to each fragment by connective tissue or bone and it was no longer possible to slide the fragments back and forth on the plate.

We still believe that complete immobilization and close apposition are the most important factors in the healing of a fracture of the shaft of a long bone.

Whether or not pressure stimulates union of cortical bone is questionable. Here there are two broad surfaces of devitalized bone which tend to be covered by new appositional bone and fused by this new bone, as well as by periosteal and endosteal callus. Pressure sufficient to cause actual microscopic contact of the two surfaces could theoretically prevent them from being covered by new bone, because cells could not grow between the two ends. Whether or not pressure applied to the shaft will stimulate the production and ossification of periosteal and endosteal callus we do not know.

SUMMARY

When infection occurred, the fractures failed to unite and, within the time limits of this experiment, the picture presented was essentially the same regardless of the type of fixation used. In clean wounds in Group I, progress of union was about the same with both types of plates, with a slight advantage in favor of the Eggers plate. Although accurate measurements were not used, we did not see evidence of the fragments sliding on the plates after the callus had formed. With clean wounds in the second part of the experiment, progress of the union was ahead on the side treated with the Eggers plate except in those animals in which the nail fitted snugly and in these it was in favor of the nail. We do not feel that the medullary nail delays union, but rather that lack of fixation due to a poorly fitting nail may delay union. Within the scope of this experiment it appears that fixation and apposition of the fractured fragments are more important in obtaining union than the pressure of weight-bearing.

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DISCUSSION

Dr. LeRoy C. Abbott, M.D., San Francisco, California: I am keenly interested, as I have been for a number of years, in the work on which Dr. Reynolds and Dr. Key based their paper on fracture healing after fixation with standard plates, contact splints, and medullary nails. In 1928, while Dr. Key and I were associated at the Shriners' Hospital for Crippled Children in St. Louis, we secured union in patients with massive destruction of the head and neck of the femur by apposition of cancellous bone surfaces maintained by wide abduction in plaster. Dr. Key followed this by the use of pins and turnbuckles and secured very early union by compression of cancellous bone surfaces. At that time, Dr. Key felt that compression was the contributory factor in the production of early union. In view of their more recent experimental work, both Dr. Reynolds and Dr. Key are of the opinion that fixation of the fracture is far more important than any degree of compression which can be obtained. I have felt that compression of cancellous bone surfaces does something to hasten union. It may be, as Charnley stated, that the value of compression of cancellous bone surfaces lies in the interdigitation of the trabeculae with gradual diminishing of the space which must be filled in by bone.

I should like to mention that Dr. Floyd Jergensen, one of my associates at the University of California School of Medicine, has been carrying on experimental work relative to fixation of fragments by means of one or several plates. He has secured union without opening the medullary canal, without removal of scar from between the bone ends, and without functional weight-bearing until both clinical examination and roentgenograms have indicated union. Recently, I asked him if he thought the plates with rigid fixation would bring about union of the fractures. He replied modestly that, at this time, he could not answer, but that he did not think the plates would do harm.

Dr. George W. N. Eggers, Galveston, Texas: About the contact compression idea, Dr. Reynolds is correct in stating that after a time one does not see any migration of the fractured ends of the shafts. We have measured a great many teleoroentgenograms of fractured femora and tibiae with a micrometer and, of those on which pressure was exerted, there was practically no change in length of the bone or any migration of fragments. We wondered about this for a bit until we examined our experimental work carefully, and you, too, will find that, where pressure is exerted, absorption and osteogenesis occur concurrently. I think that explains the fact which he mentioned. It is erroneous to get the idea that I hold that the bone is absorbed during any period of time. It is only absorbed and not replaced when the compression is absent. When the compression is present, osteogenesis and absorption are going on simultaneously. Now the second point in the healing of shaft fractures is this, — the ends of the bone are dead. This dead bone does not unite. The shaft is a bony cylinder. It unites around the outer circumference and the medullary area. This is one argument against the intramedullary nail, which I won't go into; but the intramedullary nail decreases medullary healing, although it does compensate for this by longer stabilization of the fracture site. The last part of a shaft fracture to heal is that dead bone which is in apposition and which must be replaced. I think that there is no question about the fracture line; the compact bone in this area is the last to show complete osteogenetic repair. The bone which first maintains the structure is that new bone which is formed early, and under the forces of compression and contact it matures and stabilizes the fracture. Moreover, we have shown that replacement occurs at right angles to the lines of force, and that replacement explains a great many things in regard to the invasion of areas and also the progress of what is known as "creeping substitution". This has to be looked into very carefully in order not to get some erroneous ideas about compression.

Dr. Key (closing): If union occurs normally, the devitalized ends of the fragments are incorporated in the new bone (either membranous in origin or from the cartilaginous callus or from both) and no shortening occurs as a result of its resorption. The dead bone may persist for months or even years after the fracture has

(*Continued on page 616*)

AN EXPERIMENTAL STUDY OF THE EFFECT OF CORTISONE ON THE HEALING PROCESS AND TENSILE STRENGTH OF TENDONS *†

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From Duke University School of Medicine, Durham

INTRODUCTION

The process of tendon repair was described with accuracy as far back as the seventeenth century [1]; the most extensive work was that of Mason and Shearon, who in 1932 observed and recorded in detail the sequence of tendon healing in dogs. It is evident that tendon ends will heal if they are adequately approximated. A formidable problem, not yet solved, is the prevention of tendons from adhering during healing to the surrounding tissues with a subsequent loss of gliding and function.

Numerous materials have been used to limit the formation of peritendinous adhesions without interference with tendon healing. Among these materials have been metals [9], catgut [7], cellophane [12], polyethylene [4], muscle, and fat. None of these have been satisfactory. Since the early reports of Ragan and his associates, there have been numerous articles in the literature which concern the effects of intramuscular injections of cortisone on the activity of mesenchymal tissue, both in man and in experimental animals. The dosage of cortisone, mode of administration, species variability in reaction to cortisone, and the nutrition of the experimental subject have caused difficulty in arriving at specific, valid conclusions. However, it can be said that, in general, intramuscular injections of cortisone, when given in sufficient quantity, will suppress the fibroblastic reaction to injury in experimental animals. A recent article by Carstam described the effect of cortisone given intramuscularly on the formation of peritendinous adhesions in rabbits. He concluded that the quantity of adhesions was less when cortisone was used than when it was not used. There is nothing in the literature to indicate how cortisone administered intramuscularly affects tendon healing and peritendinous reaction after tendon injury or tendon suture in dogs.

This study was undertaken to answer two questions: (1) Will cortisone prevent peritendinous fibrosis during tendon healing? (2) Will tendons heal with adequate function while cortisone is being administered?

MATERIAL AND METHODS

Dogs were chosen as experimental animals. The average weight was twelve kilograms and the average age was three years. The nutrition of all the animals was good. Both the control dogs and the dogs treated with cortisone ate well. The diet consisted of standard dog food, supplemented daily by ascorbic acid given intramuscularly. The quantity and kind of food used was sufficiently similar in both groups to eliminate nutrition as a variable factor.[5] Eosinophil counts, determination of urinary sugar, weight, and blood-pressure readings were not done. None of the dogs showed adverse side reactions to this dosage of cortisone.

Twenty-one dogs were treated with cortisone. Each animal in this group received ten milligrams of cortisone per kilogram per day; this was given intramuscularly in two doses. The size of this dose was not considered excessive when compared with the dosage found in other experimental data [2,5,6,11].

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**Orthopaedic Fellow, National Foundation for Infantile Paralysis, Inc., Georgia Warm Springs Foundation—Duke University Training Program.

Intraperitoneal sodium pentobarbital was used for anaesthesia. In dogs the heel cord can be separated easily into two distinct segments. In all of the dogs used in the experiment one segment of each Achilles tendon, as well as a flexor tendon in one forefoot, was sectioned. This provided a total of three tendons per dog for observation. In order to immobilize the extremities after tendon suture, plaster-of-Paris reenforced with strips of aluminum was used in conjunction with crossed, heavy Kirschner wires drilled through the joints above and below the suture line. Intramuscular injections of aqueous penicillin were given to each dog for seven days. Infection about the tendon sutures occurred in two control animals which were not included in the final analysis.

All surgery was done with sterile technique. The procedures were performed by the same persons and

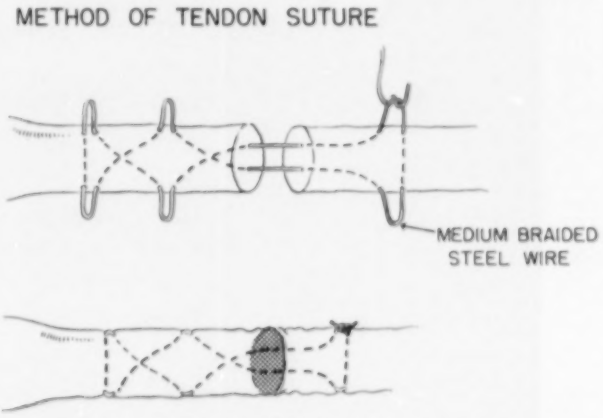

FIG. 1

Showing method of tendon suture. Medium, braided steel wire was used as the suture material. The knot was tied in the distal segment of the severed tendon. The "pull-out" technique was not satisfactory because the tendon ends could not be approximated adequately. The wire was taken out by clipping of the knot and application of traction to the wire after the gross specimen had been removed.

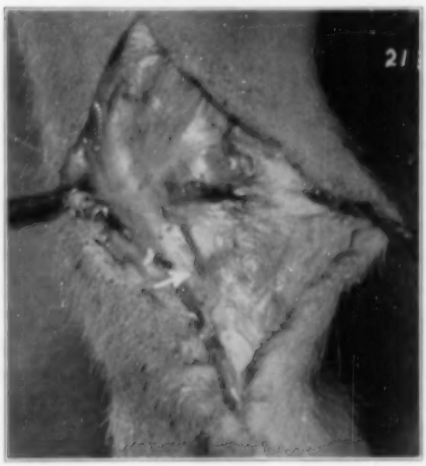

FIG. 2

FIG. 3

Fig. 2: This gross specimen of a control tendon was obtained twenty-one days after the tendon and its sheath had been cut and immediately resutured. No cortisone was used. The suture line was filled with a dense fibrous tissue which was adequate to hold the tendon ends together, but which, on histological examination, was found not to be mature. The tendon was densely adherent to the surrounding tissues which held the tendon segments immobile.

Fig. 3: A twenty-one-day specimen of tendon treated with cortisone. The tendon had been cut twenty-one days prior to the time the specimen was removed from the extremity. Intramuscular injections of cortisone were given each day from the time of the tendon section until the animal was sacrificed. The peritendinous tissues were separated easily from the sutured tendon. There was close approximation of the suture line. The tendon sheath was slightly thickened. Very little granulation tissue or hemorrhage was present. Less dissection was necessary in exposing and removing this tendon from its bed than was needed for the same procedures in the control dogs. Upon movement of the foot, the tendon was seen to glide with minimal restriction. (Compare this with Fig. 2.)

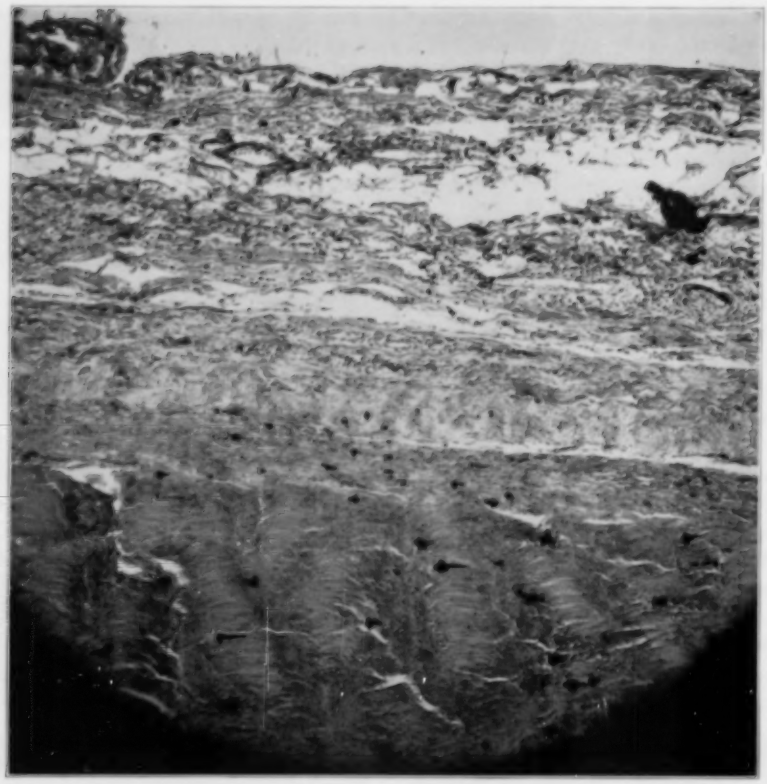

FIG. 4-A

High-power view (× 67) taken at a distance of one centimeter from the suture line of a control tendon examined at twenty-one days. The periphery of the tendon is made up of a dense sheath, which is thick, with moderate cellularity.

the operative technique was consistent throughout. The tendons were sectioned and sutured with medium, braided stainless-steel wire, either immediately or after one week (Fig. 1). At intervals of from one to six weeks after the tendon surgery, the dogs were sacrificed, the wounds were opened, and the tendons were photographed *in situ*. The suture line and the adjacent inch of tendon with its sheath and fibrous tissue were removed *en bloc* and examined histologically. Hematoxylin and eosin and connective-tissue stains were used to prepare the sections. Twenty tendons were tested to determine the amount of weight in grams required to rupture each tendon at its suture line.

Sixty-nine tendon sutures were done on twenty-three dogs. The animals were divided into three groups.

Group I consisted of dogs receiving no cortisone. Twenty-two tendon sutures were completed in this group. Observations were made at seven, fourteen, twenty-one, twenty-eight, and forty-two days. The operations done within this group varied. Tendons were sectioned and after a seven-day delay were sutured. Scarification of the intact tendon and its sheath was done by vigorous scraping of the tendon. Also, tendon severance within the sheath, done by the puncture method, was performed without excision or destruction of the sheath.

Group II included forty-seven tendon sutures in dogs receiving cortisone intramuscularly. The operative technique used was the same as that in Group I. The time interval for examination of the tendons varied from seven to forty-two days. Delayed sutures,

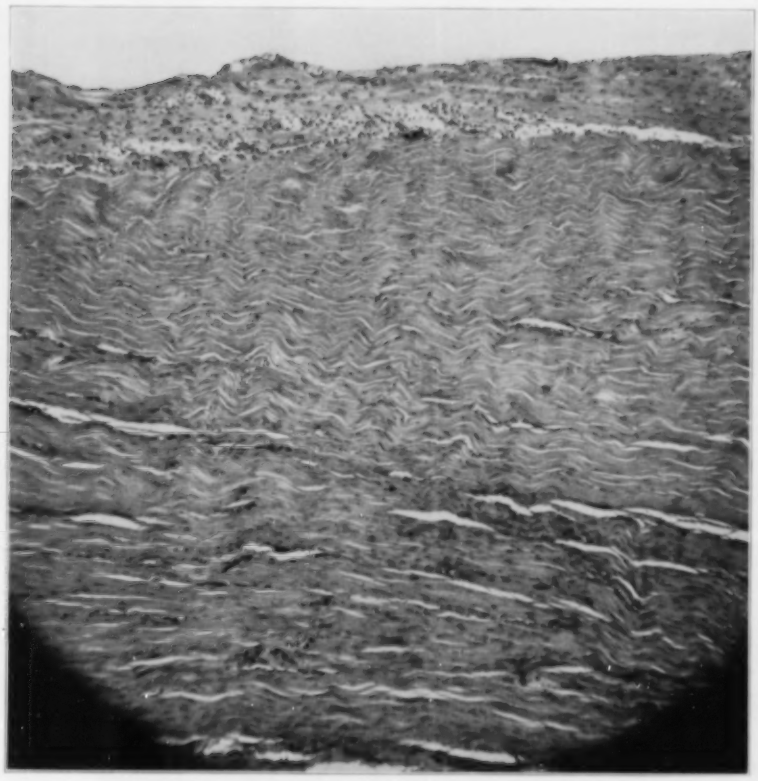

FIG. 4-B

High-power view (× 67) of a cortisone-treated tendon examined at twenty-one days, which shows the fibrils to be of the same density and maturity, but with a thin peritendinous covering.

scarification, and tendon severance within the sheath also were done in this group. In order to determine whether excessive fibrous-tissue proliferation would occur after withdrawal of cortisone, the drug was discontinued after seven, fourteen, or twenty-one days and a period of immobilization was maintained.

Group III included twenty tendons chosen from Groups I and II. These were used to determine the strength of the tendons after they had been sutured and allowed to heal. Time intervals of seven, fourteen, and twenty-one days after tendon suture were chosen for examination. Parallel series were tested; these consisted of ten tendons treated with cortisone and ten tendons not treated with cortisone.

Gross and microscopic examinations were made in each of the three groups.

GROSS AND MICROSCOPIC EXAMINATION

Photographs were taken before the delayed suture and at the time of autopsy. Findings noted particularly were: the presence or absence of infection, the ease with which the incision could be opened, the density and quantity of adhesions between the skin and the peritendinous tissue, the quantity of fibrous tissue surrounding the tendon, the condition of the suture line, the density and quantity of fibrous tissue between the underlying bone and the tendon sheath, and the state of regeneration of the tendon sheath.

In specimens which were examined *seven days* after section of the tendon and its sheath the following difference was noted between the control tendons and the cortisone-treated

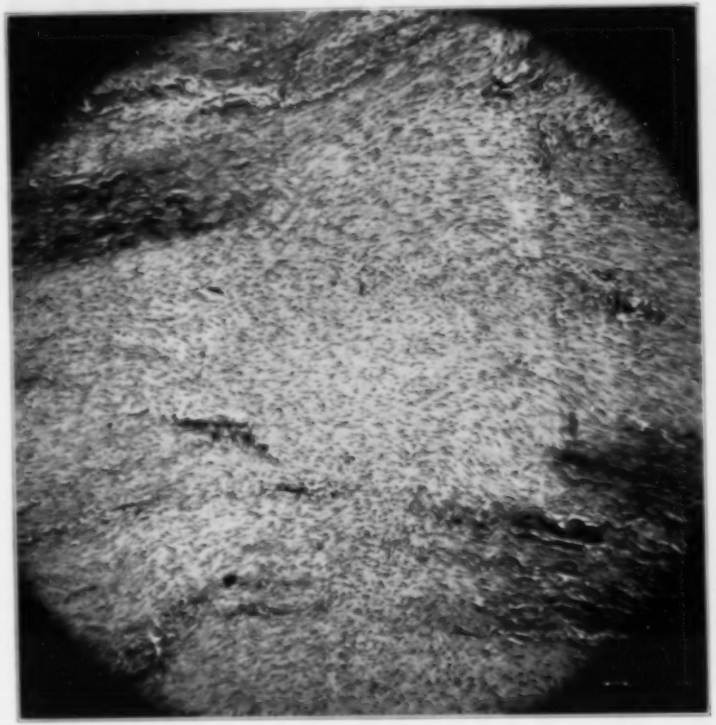

FIG. 5-A

High-power view (× 67) shows the suture line of a control tendon which was severed and then was resutured immediately. The specimen was removed twenty-one days after the initial suture. Cortisone had not been used.

The area between the tendon fibrils is filled with mature elongat ed fibrocytes. These are lined up regularly and show evidence of a good fibrobla stic response secondary to injury.

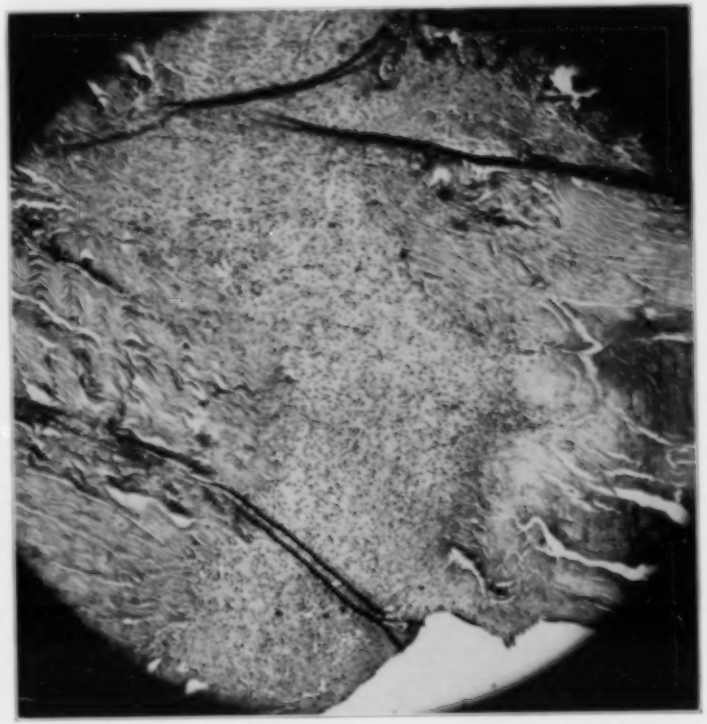

FIG. 5-B

High-power view (× 64) of a cortisone-treated tendon which was observed twenty-one days after resuture. The suture line is not so dense as that of the control tendon. The cells are haphazard and are not lined up like those in the control specimen. Both specimens show evidence of a good fibroblastic response, although the maturity of the fibrous tissue in the tendon treated with cortisone is less than that in the control tendon.

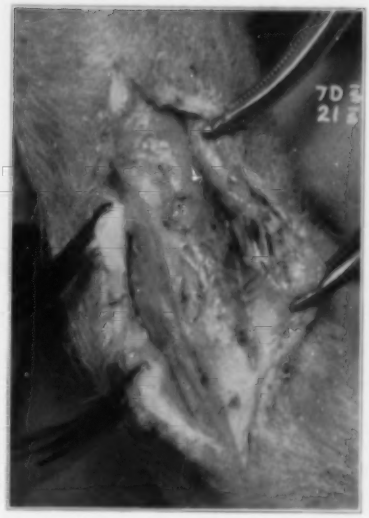

FIG. 6-A

FIG. 6-B

Fig. 6-A: Photograph of a control tendon examined twenty-eight days after initial surgery. Seven days elapsed from the time of cutting the tendon to the time when the tendon was sutured. Cortisone was not given. At the time the gross specimen was removed, no motion of this tendon was present. The tendon was not well delineated from the subcutaneous tissue or the tissues covering the bone. Furthermore, the approximation of the cut ends of the tendon after the seven-day delay period was more difficult than the primary suture. This specimen showed more peritendinous fibrosis after twenty-eight days than did the specimen which was cut, resutured immediately, and observed for twenty-eight days.

Fig. 6-B: Photograph of a twenty-eight-day specimen for which the same routine was carried out as that used on the specimen seen in Fig. 6-A, except that cortisone was administered to this dog during the twenty-one days following the delayed suture. A delay of seven days occurred following the initial cutting of the tendon and, during this time, no cortisone was given. The tendon was easily uncovered at the time it was removed from the extremity. The suture line was strong and the fibrous tissue between the tendon ends was holding them firmly. Gliding was present to a greater extent than in the control specimen.

Fig. 6-C: Photograph of a specimen from a dog treated with cortisone. The tendon was cut and a delay period of seven days was allowed to elapse before suture. During this seven-day interval, as well as during the twenty-one-day healing period, the dog received cortisone. This tendon was loose in its bed and surrounded by a thin covering of fibrous tissue. The delayed primary suture was easier to perform than in the animals in which no cortisone had been administered. Firm immature union occurred during the twenty-one-day healing period, despite the use of cortisone.

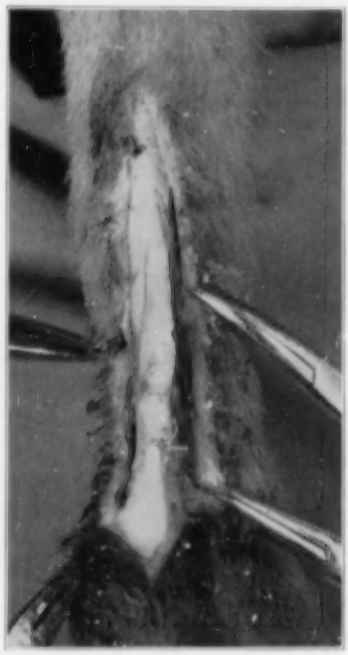

FIG. 6-C

tendons: The severed ends of the control tendons were bulbous and adherent to the surrounding tissue. There was proliferation of fibrous tissue in the space between the retracted ends. The tendon segments were adherent to the superficial fascia. If the severance had been performed within the tendon sheath by the puncture method, less fibrous reaction occurred even in the seven-day interval. The cortisone-treated tendons showed a minimal quantity of fibrous tissue between the separated ends. The ends were distinct and smooth, with little oedema. The overlying and surrounding tissues could be separated easily from the tendons.

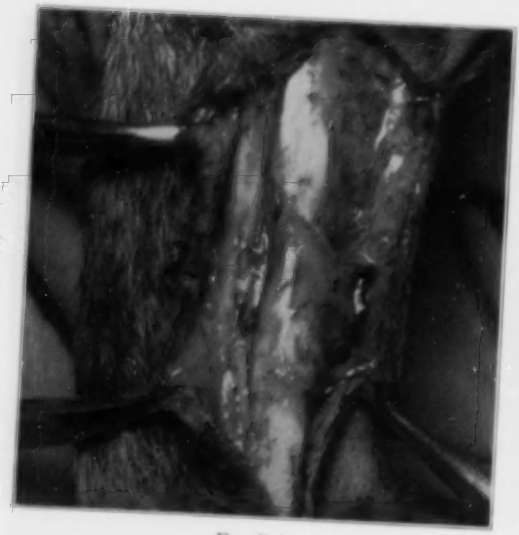

FIG. 7-A

FIG. 7-B

Fig. 7-A: Gross specimen of a tendon which had been sectioned and resutured immediately; this was followed by treatment with cortisone for twenty-one days and without cortisone or immobilization for an additional twenty-one days. Moderate fibrosis was present, but the tendon was clearly delineated and moved when the distal portion of the extremity was moved.

Fig. 7-B: Gross specimen of a control tendon observed for forty-two days. No cortisone was used during the entire period. Immobilization after suture was carried out for the first twenty-one days and active motion was allowed for the last twenty-one days. The tendon had lost its identity; it was firmly bound to the subcutaneous tissue and there was no gliding when the distal portion of the extremity was moved. The microscopic sections showed a dense proliferative sheath surrounding the tendon.

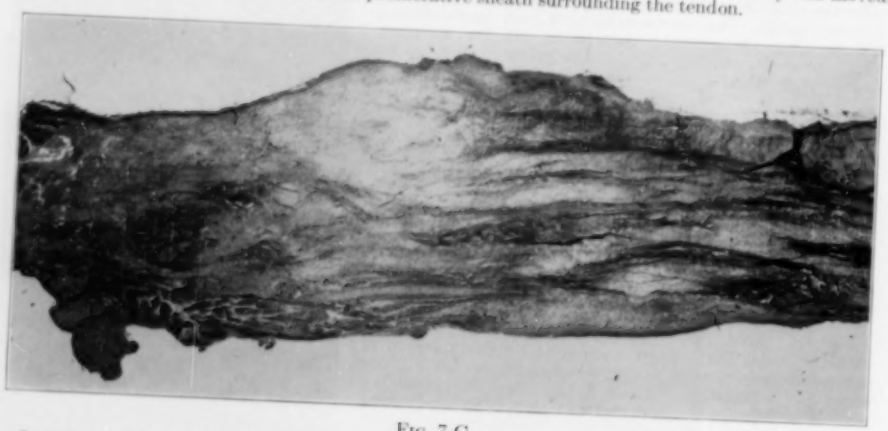

FIG. 7-C

Low-power view (× 6.5) of the specimen shown in Fig. 7-A. Continuity of the tendon has been reestablished. The suture line is not surrounded by an abundance of peritendinous tissue but is made up of fibrocytes and fibrils.

At *twenty-one days*, the control tendons which had been cut and immediately resutured were surrounded by a dense, firm, adherent mass of fibrous tissue. In no instance in the control series were the tendons clearly delineated and the peritendinous tissues were not easily separated from the surrounding deep and superficial tissues. Figure 2 shows the suture line filled with fibrous tissue and an abundant amount of peritendinous connective tissue. In another control animal the excised gross specimen illustrated the continuity of the tendon end. The fibrous tissue, although holding the tendon ends, was found not to be mature on histological examination. When one specimen was stripped

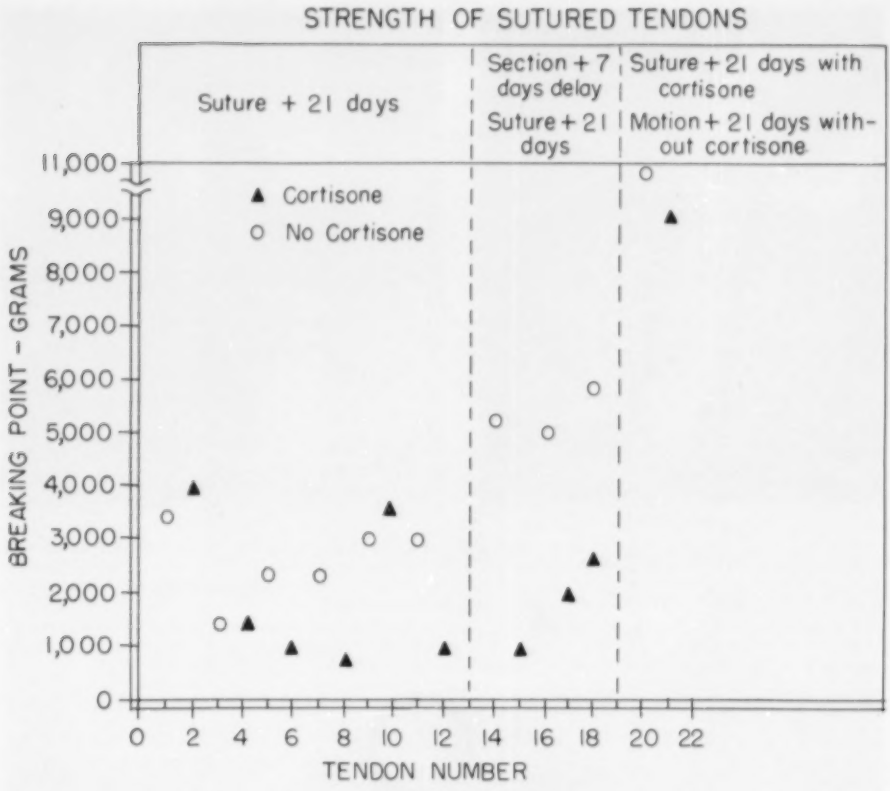

CHART I

Graphic representation comparing the strength of the sutured tendons in both the control tendons and the tendons treated with cortisone. The numbers listed horizontally refer to the specimen number and do not indicate the number of tendons in each group.

The tensile strength in general reflected the fact that healing occurred in spite of the cortisone and that, after a six-week period had elapsed, solid union was present regardless of the use of cortisone. Tensile strength was usually greater when cortisone had not been used.

of all peritendinous tissue, the incomplete end-to-end healing was evident. It was the peritendinous tissue which added strength.

The cortisone-treated specimens examined at twenty-one days (Fig. 3) showed adequate healing of the skin and less fibrous tissue around the tendons than the controls. Those adhesions which did occur were not so firmly connected to the surrounding tissues as were those in the control specimens. The specimen in Figure 3 shows the suture line in the smooth heel cord with a minimal amount of hemorrhage and little granulation tissue. Less dissection was required to expose this cortisone-treated tendon than to expose the control tendon. Tendon healing had also occurred in the latter. By gross examination healing appeared to be present both in the tendons treated with cortisone and in the control tendons.

Histological examination of the specimens examined at twenty-one days verified the gross evaluation. A low-power view of the suture line of a control tendon examined at twenty-one days showed the tendon sheath to be wide; the suture line was filled with dense fibroblasts, but continuity was not complete between the mature fibrils of the tendon ends. This coincided with the appearance of the tendons illustrated in the work of Mason and Shearon. Microscopic examination of a tendon treated with cortisone showed that the suture line was filled with fibrous tissue similar to that seen in the control specimen,

FIG. 8-A

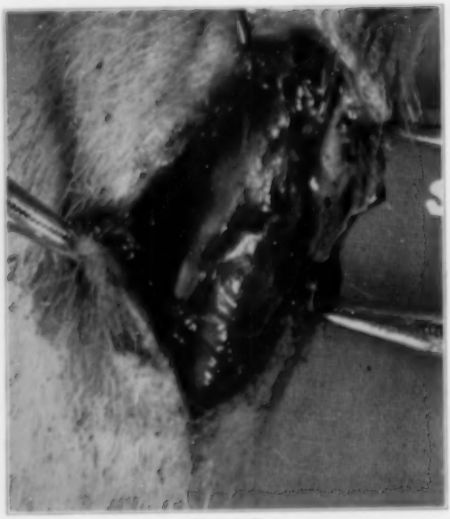

FIG. 8-B

Fig. 8-A: Gross specimen of a tendon which was scraped and injured locally but not cut. Cortisone was administered to this dog for twenty-one days. The appearance after treatment with cortisone shows the tendon to be well demarcated from the surrounding tissue; the tendon sheath was easily located and showed no evidence of regeneration. The tendon could glide easily.

Fig. 8-B: Specimen of a scarified tendon examined at the end of twenty-one days, during which time no cortisone was used (compare with Fig. 8-A). The surrounding fibrous tissue was dense and was strongly adherent to the subcutaneous tissue. The tendon sheath could not be identified.

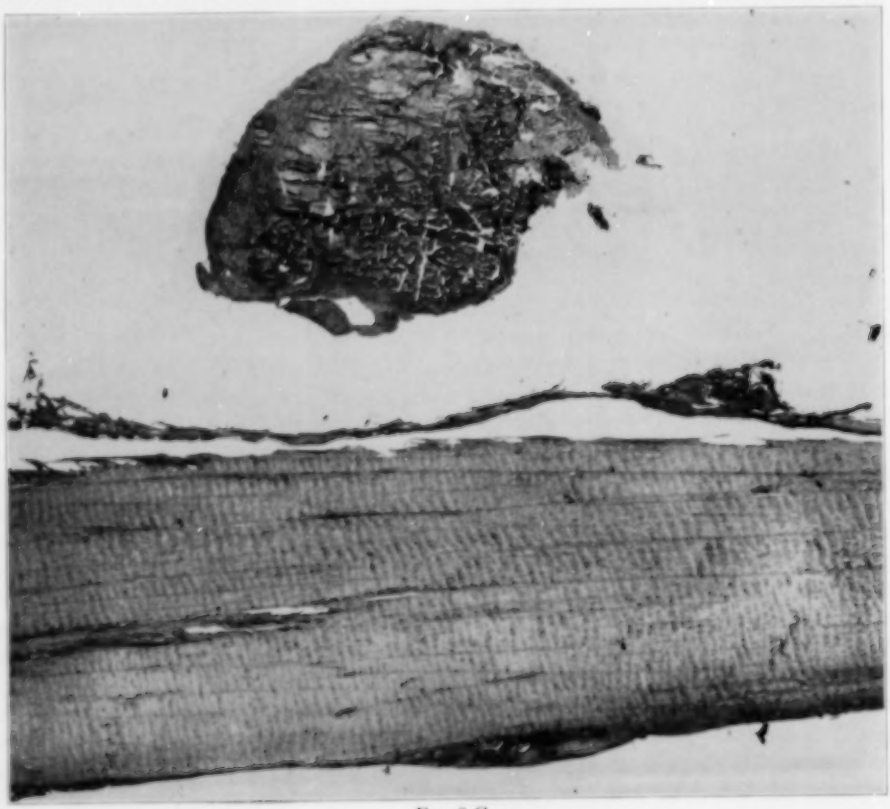

FIG. 8-C

(*See page 597*)

Fig. 8-C: Low-power view (× 6.6) of the scarified tendon which was treated with cortisone for twenty-one days. The tendon sheath is thin and there is very little adherent peritendinous tissue. The cross section is shown above and the longitudinal section below.

FIG. 8-D

Low-power view (× 6.6) of gross specimen seen in Fig. 8-B. The fibrous tissue surrounding the tendon sheath is thick and adherent. (Compare with Fig. 8-C.)

and both showed evidence of end-to-end union. The periphery of the tendon treated with cortisone did not show the thick band of fibrous tissue seen in the control.

Sections taken one centimeter from the suture line of the control tendon examined at twenty-one days (Fig. 4-A) show the longitudinal fibers, as well as the well organized, densely adherent sheath, which is much more cellular than the central portion of the tendon. Several capillaries are evident throughout this field. The section taken from the corresponding site in a tendon treated with cortisone (Fig. 4-B) shows about the same amount of cellularity and vascularity, but the thickness of the peripheral tissues is much less than in the control tendon. A high-power view of the suture line of the control tendon (Fig. 5-A) when compared with that of the cortisone-treated tendon shows a slightly different histological appearance. The suture line in the control is filled with mature, elongated fibroblasts which are in parallel alignment with the tendon fibrils. The fibrous tissue in the cortisone-treated tendon (Fig. 5-B) is less mature and has not yet assumed a parallel arrangement. Both show evidence of a good fibroblastic response consistent with the usual healing process, but the maturity of the fibrous tissues between the tendon ends is less in the specimens treated with cortisone than in the controls.

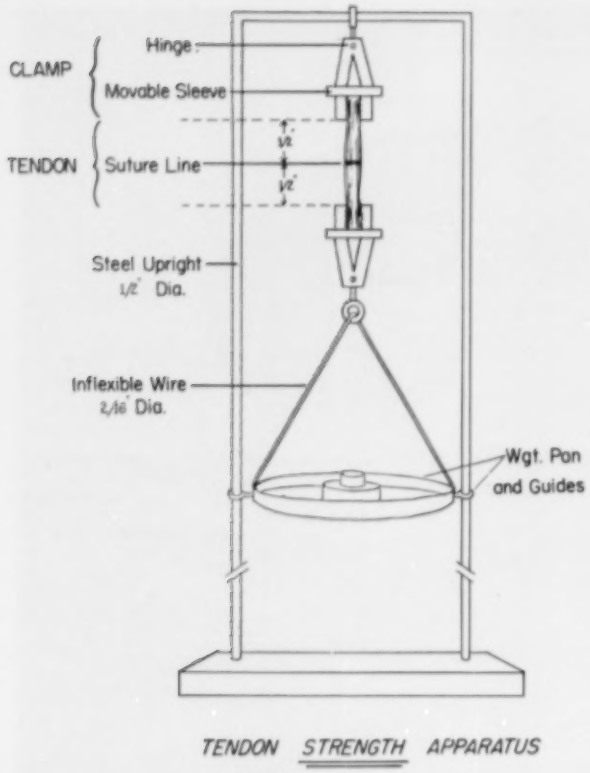

FIG. 9

Apparatus used for determining tensile strength of the tendon after resuture in both the control tendons and the tendons treated with cortisone. The strength of the suture line was determined in grams. The circumference of the tendons was taken into consideration. The tendon and its peritendinous tissue were removed intact from the extremity at the time the animals were sacrificed.

When a seven-day delay period had elapsed between the severance of the tendon and its repair, the specimen examined after twenty-one days of healing without cortisone (Fig. 6-A) showed more fibrous-tissue response and less delineation of the tendon than was present in the control in which there was no delay. This tendon after twenty-one days of healing was void of any cleavage plane. The subcutaneous and deeper tissues down to the bone formed a dense coalescent mass; this massive fibrosis eliminated gliding. Approximation of the tendon ends after a seven-day delay was much more difficult than a primary suture. Granulation tissue buried the tendon ends, which were bulbous, friable, and difficult to pull together.

The tendons treated with cortisone (Fig. 6-B) which were observed twenty-one days after a seven-day delay, during which no cortisone was used, were more readily exposed than the control tendons. The suture line was intact and the tissue between the tendon ends was firmly holding the tendon segments. A moderate amount of aberrant granulation tissue was present. More peritendinous reaction was present in this tendon than in the specimens which were sutured immediately and had received cortisone for twenty-one days.

A tendon treated with cortisone which was sutured seven days after its severance and was allowed to heal for twenty-one days (Fig. 6-C) was loose in its bed and surrounded by a thin covering of fibrous tissue. When cortisone was used during the seven-day waiting period before suture, the specimen examined at twenty-eight days showed less adherence of the tendon to the skin and deeper tissues than the specimens for which cortisone was not used during the seven-day delay. Moreover, at the time of the delayed primary suture, when the tendon had already been severed for seven days, the suture was performed easily in the group of dogs which had received cortisone. The group which had not received cortisone already had limitation of the excursion, a wider segment to bridge, and in general a tendon with little, if any, gliding.

In summary, at the end of twenty-eight days the control tendons which had had a seven-day delay formed a coalescent, dense, adherent, fibrous mass. The tendons which had had a seven-day delay without cortisone followed by twenty-one days with cortisone showed less fibrous tissue than the control tendons but more than the cortisone-treated specimens delayed for seven days, sutured, and immobilized for twenty-one days. The

FIG. 10-A

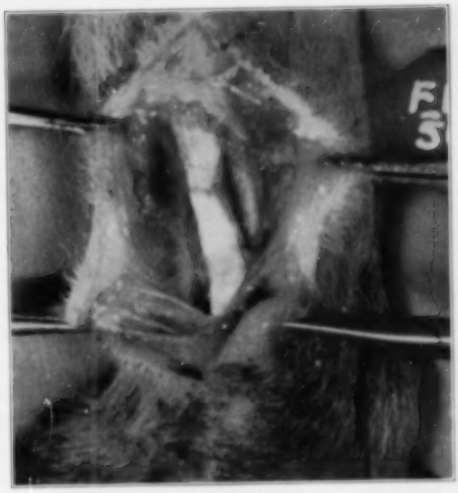

FIG. 10-B

Fig. 10-A: This twenty-one-day specimen shows a tendon which was wrapped with gelfoam for protection after the tendon had been cut and resutured immediately. The peritendinous adhesions were less dense than those in the control tendon, but more dense than those seen in the tendons treated with cortisone.

Fig. 10-B: Gelfilm, which is more firm, thinner, and more difficult to handle than gelfoam, was placed around this twenty-one-day specimen at the time of resuture. Again, the gelatin material acted as a protector for the tendon in that the adhesions between the tendon and the surrounding tissues were not dense and allowed the tendon a better area for gliding.

Healing occurred in spite of the presence of gelfilm or gelfoam.

latter group showed fewer adhesions than any of the others. Healing of the tendons was adequate, as is shown in Chart I.

In order to determine whether or not excessive fibroblastic response occurred when cortisone was discontinued, it was necessary to administer cortisone for certain periods of time, discontinue it, and then allow a period of time to elapse before autopsy. In one specimen, in which a seven-day delay period had been followed by a seven-day period of treatment with cortisone, the sutured tendon was found to be surrounded by very little connective tissue. After fourteen days, partial healing had occurred; excessive proliferation of fibrous tissue did not take place during the last seven days, when cortisone was discontinued. A microscopic section of the fourteen-day specimen revealed moderate hemorrhage, accompanied by immature fibroblasts with very little indication of excessive peritendinous adhesions. The suture line showed granulation tissue, but the cells were immature, small, and not particularly abundant. Another section illustrated the delay in regeneration of the tendon sheath in a specimen treated for one week with cortisone and one week without. Tendon sutures which were observed for forty-two days (Fig. 7-A) showed that three weeks with cortisone followed by three weeks without cortisone and without immobilization did not result in an excessive proliferation of fibrous tissue (Fig. 7-C). The fibrous tissue which did occur was soft and was not densely adherent to the skin. The control specimen (Fig. 7-B) at the end of a similar six-week period showed a mass of dense, diffuse connective tissue without distinct cleavage planes which was firmly adherent to the subcutaneous tissue and deeper structures.

Several specimens in which the tendon sheath had been completely destroyed and in which the tendon had been scarified but left intact were examined at twenty-one days. Figure 8-A represents the gross appearance. The sheath is intact proximally and its margins are well delineated. The microscopic section (Fig. 8-C) shows the appearance of the tendon treated with cortisone; little regeneration of the tendon sheath is evident and there is minimal peritendinous fibrosis in the cross section above and the longitudinal section below. The

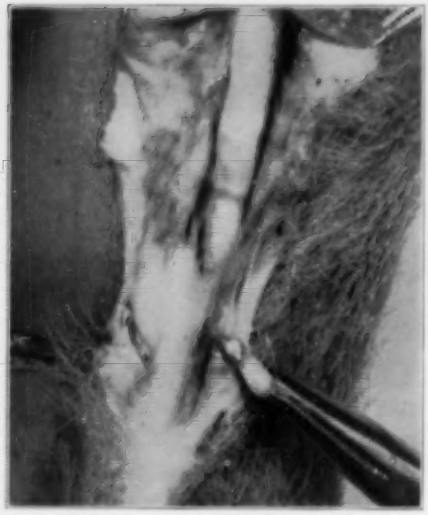

FIG. 11

This specimen was removed after the dog had received intravenous pyromen, two micrograms each day for twenty-one days. The quantity of fibrosis was less than that seen in the control group and the specimen resembled a tendon treated with cortisone. The suture line was well delineated. The peritendinous tissue was thin and the tendon was smooth. Gliding took place easily.

control tendon (Fig. 8-B) shows an abundance of peritendinous tissue and extensive adhesions to the subcutaneous areas and to the tendon proper. The microscopic specimen (Fig. 8-D) of the control illustrates the thick peritendinous reaction as seen in the cross section above and the longitudinal preparation below.

TENDON STRENGTH

In order to compare the tendon strength of the tendons treated with cortisone and those treated without cortisone, each tendon to be tested was excised with its suture line and placed in the tension apparatus (Fig. 9). Weights were added until the tendons separated at the line of suture. Chart I shows the relationship between the control tendons and the tendons treated with cortisone at intervals of seven, fourteen, and twenty-one days.

In testing for the breaking point, the peritendinous tissue was usually included with the tendon because it was difficult to remove it without damaging the suture line. This difficulty was noticed particularly when cortisone had not been used. The tension experiments indicated that at the same number of days the average strength of the controls was forty per cent. greater than that of the cortisone-treated tendons (Chart I). The average breaking point of the control tendons was at 3,950 grams and that of the tendons treated with cortisone was at 2,400 grams.

OTHER LOCAL AND SYSTEMIC THERAPY

Gelfoam or Gelfilm

The administration of a substance which affects the entire body when only a local tissue change is desired has certain disadvantages. Since gelfoam and gelfilm[3,10] are known to limit fibrous-tissue formation, these substances were implanted around six tendons at the time of suture. Figure 10-A shows a twenty-one-day specimen which had been wrapped with gelfoam. The peritendinous tissue was easily separated from the tendon and the adhesions were less in quantity and density than in the twenty-one day control. Figure 10-B is a twenty-one-day tendon which had been encased in gelfilm at the time of suture. This material was difficult to handle, but satisfactory protection of the tendon segments was possible. At autopsy the tendons were smooth and resembled several of the tendons treated with cortisone. Neither the gelfoam nor the gelfilm were completely absorbed at twenty-one days. In one animal in which cortisone had been given intramuscularly in conjunction with the gelfoam, there was a small quantity of fibrous tissue, but there were no noticeable peritendinous adhesions in the areas where gelfoam had been used.

Pyromen

This is a non-protein bacterial derivative, compounded mainly of a complex polysaccharide which affects the pituitary-adrenal system[13]. It has revealed some ACTH-like effects. One dog was given intravenous injections of pyromen, two micrograms each day for twenty days. Immobilization was carried out during the period of tendon healing. The dog exhibited a febrile reaction each day while the drug was being used. Examination at

twenty-one days showed less fibrous tissue than was present in the control group (Fig. 11). The specimens resembled the tendons treated with cortisone. The tendon was smooth, its suture line was healing, and there was a minimum of peritendinous adhesions.

CONCLUSIONS

1. The daily administration to dogs of ten milligrams of cortisone per kilogram of body weight inhibited excessive formation of peritendinous fibrous tissue.

2. Cortisone administered during the waiting period prior to the delayed suture made approximation of the tendon ends easier than in the control group.

3. The administration of cortisone to dogs in which tendons had been severed and resutured did not prevent end-to-end healing of the tendons.

4. Regeneration of the tendon sheath was delayed during the administration of cortisone.

5. The breaking point of a sutured tendon treated with cortisone was consistently less than in the control tendons. Although the tendons treated with cortisone were 40 per cent. weaker than the controls, healing in both was adequate for function.

6. Gelfilm and gelfoam used locally diminished the peritendinous adhesions during healing of sutured tendons in dogs.

7. Pyromen administered intravenously to dogs diminished the quantity of fibrous tissue around healing tendons.

NOTE: The cortisone used in this study was provided in part by Merck and Co., Inc. The pyromen was provided by Baxter Laboratories.

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THE USE OF HYDROCORTISONE ACETATE (COMPOUND F ACETATE) IN THE TREATMENT OF SOME COMMON ORTHOPAEDIC CONDITIONS *

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Injection of hydrocortisone acetate (compound F acetate) into joints, bursae, and other body cavities and tissues produces a temporary local antirheumatic or anti-inflammatory effect. This was described in 1951 by Hollander and his associates [7] in cases of rheumatoid arthritis, acute traumatic arthritis, acute gouty arthritis, bursitis, and the arthritis and pleurisy associated with lupus erythematosus. Similar results have been reported subsequently by other investigators [1-6, 8-14]. This local effect is more than simple analgesia, because studies of the synovial fluid from rheumatoid joints reveal a decrease in the number of neutrophils, a decrease in temperature of the joint, and an increase in the viscosity of the synovial fluid after the intra-articular injection of hydrocortisone acetate.

Cortisone, on the other hand, has exhibited an inconsistent local antirheumatic effect when it is injected intra-articularly; in fact, Hollander and his associates reported that the intra-articular injection of fifty to sixty milligrams of cortisone in some instances led to local irritation.

PRESENT STUDY

The purpose of this review has been to evaluate the clinical results of the intra-articular injection of hydrocortisone acetate in the treatment of certain of the arthritides, bursitis, and epicondylitis (tennis elbow).

In this series, 690 injections of hydrocortisone acetate were given to 241 patients without significant untoward reactions or complications. Two or more joints have been injected frequently at the same time in treatment of the arthritides. All injections were done under aseptic conditions after surgical preparation of the skin and sterile draping of the part involved. Local anaesthesia was used in our series for a fourth of the injections; in a few instances, thiopental sodium (pentothal) was administered intravenously to induce general anaesthesia, particularly in apprehensive or uncooperative patients for whom removal of specimens of synovial membrane for biopsy was also planned.

RHEUMATOID ARTHRITIS

Hydrocortisone acetate was injected into 521 joints and two bursae of 148 patients who had rheumatoid arthritis. The following numbers of injections were made: knee, 448; ankle, thirty; hip, sixteen; elbow, sixteen; shoulder, five; interphalangeal joint, four; wrist, two; and the olecranon bursa, two. The general activity of the rheumatoid process was considered mild in fourteen patients, moderate in seventy-two, and severe in sixty-two. Roentgenograms of selected joints revealed no significant changes in twenty-nine patients, osteoporosis in seventeen, and destructive changes in 102.

Evaluation of improvement after injections took into consideration not only changes in subjective complaints, such as pain, stiffness, and functional impairment, but also changes in objective signs, such as swelling, tenderness, redness, warmth, and range of

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motion of the joints. The degree of improvement was termed "marked" if 75 to 100 per cent. relief was obtained, "moderate" if 50 to 74 per cent. relief was obtained, and "mild" if 25 to 49 per cent. relief was noted. Improvement of less than 25 per cent. was not considered significant.

Results

The first manifestations of improvement, which usually were decreased pain and stiffness, took place within the first twelve or twenty-four hours after injection. Objective signs of improvement, such as decreased tenderness, swelling, redness, warmth, and increased range of motion, generally followed subjective signs of improvement within a few hours. Improvement in some patients could be noted within an hour or two, even in patients who had not received an anaesthetic agent. Only rarely was the onset of improvement delayed beyond twenty-four hours and in no instance beyond forty-eight hours.

Marked improvement was noted in the condition of 49 per cent. of the injected joints; the improvement was moderate in 35 per cent., mild in 13 per cent., and insignificant in 3 per cent. This antirheumatic effect persisted for two to eight days after the majority (78 per cent.) of the injections and for nine to twenty-one days in some (12 per cent.). A small number of injections (7 per cent.) were followed by improvement lasting more than twenty-one days; these remissions lasted several months in some instances. Evidence of concurrent improvement in the general status of the rheumatoid arthritis, either spontaneous or induced by general measures of treatment, was present in almost all instances of such prolonged remissions and in most instances in which the improvement lasted for more than eight to ten days.

The local effect persisted for less than two days after 3 per cent. of the injections. Trauma caused by excessive use of the injected joint appeared responsible in some of these cases for the rapid recurrence of symptoms; the cause of the relatively short duration of effect in others was not apparent, but it did not appear to be related to worsening of the general condition of the patients. Although the dosage of hydrocortisone acetate in this series varied from 12.5 to 100 milligrams, it would appear that in most instances 37.5 milligrams was adequate in medium-sized or large joints, whereas doses of 12.5 to 25 milligrams were sufficient in smaller joints. No appreciable additional benefit was derived from larger doses in most instances, but they did not produce local irritation. The effect of large doses appeared to be greater or more prolonged in only a few instances.

Cortisone and Corticotropin

Cortisone was being used orally in 39 per cent. of these patients and corticotropin was being given to one patient when the intra-articular injections of hydrocortisone acetate were performed. This oral treatment influenced the results of the injections only in that patients whose arthritis was generally under good control tended to have a somewhat more prolonged benefit from the injection of hydrocortisone acetate. Variations in oral dosage of cortisone within limits of dosages used to maintain general improvement had no effect on the results of intra-articular therapy.

Failures

Insignificant or no benefit resulted from intra-articular injections of hydrocortisone acetate in seven of these 148 patients. It appeared probable that the joints in four of these did not improve because the articular manifestations were caused largely by destructive changes rather than by inflammatory synovial reactions. Lack of response in one patient appeared to be caused by bleeding into the synovial cavity after the concurrent removal of a specimen for biopsy by needle aspiration. The bleeding was verified by aspiration two days later; another injection of hydrocortisone acetate at that time led to great improvement. No explanation for the failure was apparent in the other two

patients; one of them obtained good results from subsequent injections into the same joint, while injections were not repeated in the second patient. In an eighth patient, no effect was noted after injection into an olecranon bursa; after subsequent excision of the bursa, microscopic examination revealed fibrosis but no inflammatory changes.

Complications

No serious complications occurred as a result of this procedure, but a few minor reactions were noted. Increased swelling and soreness were encountered in the knee of one patient for one or two days after each of two injections; this reaction was followed each time by gradual improvement. Minor increases in the swelling for an hour or two after the injection were noted in a few patients. The cause of this reaction was not determined; suggested possibilities are slight hemorrhage into the joint or irritation of the synovial membrane by one of the constituents of the injected suspension.

Systemic Effects from Hydrocortisone Injected Intra-Articularly

Systemic as well as local effects were noted clinically after intra-articular injections of hydrocortisone acetate in thirty-one (21 per cent.) of the 148 patients who had rheumatoid arthritis. There was clinical improvement in involved but uninjected joints in this group, the effect being similar in nature, both subjectively and objectively, to that which results from the oral or intramuscular administration of cortisone. Its occurrence indicated that at least part of the hydrocortisone acetate injected into the synovial cavity was absorbed into the blood stream and reached the general circulation. Usually the systemic manifestations were mild in degree, were first noted about two to twenty hours after the injections, and were of short duration (one or two days). Most of the systemic reactions (90 per cent.) were noted after the injection of 50 milligrams or more of hydrocortisone, whereas a few systemic reactions (10 per cent.) were noted after injection of 37.5 milligrams or less. Women, who in general tend to be somewhat more susceptible to the effects of cortisone administered orally or intramuscularly, appeared to be slightly more prone to the development of systemic effects from intra-articularly injected hydrocortisone acetate. Likewise, patients who were experiencing symptoms during reduction or withdrawal of cortisone and were unusually sensitive to small changes in dose also were prone to note systemic effects from the intra-articular administration of hydrocortisone acetate. The greatest systemic effect occurred in a woman in whom symptoms caused by reduction of cortisone were present and to whom 225 milligrams of hydrocortisone acetate was administered intra-articularly, 37.5 milligrams into each of six joints, at one time.

The systemic effects were noted within two and a half hours; they were extensive in degree for two days and were persistent to some extent for six days. The degree of local antirheumatic effect from use of hydrocortisone acetate apparently did not influence the incidence or degree of systemic effect.

Indications

It appears from our study that the intra-articular use of hydrocortisone acetate is primarily helpful in those patients in whom the treatment of a few readily injected joints is of special concern. Such patients may include the following: (1) those who have but a few joints involved, for example, one or both knees; (2) those in whom the generalized rheumatoid arthritis is satisfactorily controlled by use of cortisone or other measures but in whom the synovitis in a few joints is not adequately brought under control by safe dosages of other medicaments, or in whom flare-ups occur in a few joints previously controlled by treatment; and (3) those in whom use of cortisone and corticotropin is contra-indicated because of complicating disease and in whom other, general measures of treatment are not sufficient.

OSTEO-ARTHRITIS

Hydrocortisone acetate was injected 102 times into the joints of forty-eight patients who had osteo-arthritis. The knee was injected eighty-eight times and the hip fourteen times, the usual dose being 37.5 milligrams. Beneficial effects consisted mainly in relief of pain and stiffness in the injected joint and occasionally in increased range of motion. When improvement occurred, it began within twenty-four hours. The degree of improvement was graded as "marked" after 38 per cent. of the injections, "moderate" after 34 per cent., and "mild" after 7 per cent. No significant benefit was noted after 21 per cent. of the injections. Improvement persisted for one to eight days in 60 per cent. of the cases, from nine to twenty-one days in 30 per cent., and for more than twenty-one days in 10 per cent. When improvement was prolonged more than seven or eight days, other factors, such as increased rest and limitation of weight-bearing activities, appeared to be of great importance in the maintenance of the temporary benefit which resulted from injection of hydrocortisone acetate. Repeated injections did not lead to progressively greater or more prolonged improvement, in contrast to the experience reported by other investigators. No instances of prolonged benefit were observed in patients who continued to subject the involved joint to overuse. In general, the more damage present in the joint, as judged by changes in the roentgenograms, and the more use to which that joint was subjected, the shorter was the duration of benefit after intra-articular therapy. Benefits from injections in osteo-arthritic patients were most striking in those who were suffering from an acute or subacute flare-up of the condition, presumably caused by a superimposed synovitis. Relief of symptoms apparently occurred more rapidly after intra-articular administration of hydrocortisone acetate than would be expected in patients treated by ordinary general measures, such as rest in bed, physical therapy, and use of salicylates.

The only complication which occurred in these forty-eight patients was a single instance of increased swelling and pain for three days after the injection. The condition of this joint gradually improved greatly. It is possible that bleeding into the joint consequent to the injection was the cause of this complication.

Two indications apparently exist at present for the intra-articular injection of hydrocortisone acetate in cases of osteo-arthritis,—namely, the need to control acute or subacute flare-ups of osteo-arthritis, whether spontaneous or precipitated by abuse of the affected joint, and the need to obtain additional symptomatic relief in osteo-arthritic patients who continue to have major degrees of discomfort despite maximal practical use of conservative measures of treatment. It is doubtful that injections of hydrocortisone acetate should be given merely to provide relief of pain for a temporary period during which the patient is permitted to subject the involved joint to overuse. Such a policy in the long run may lead to progressively increasing damage to the joint.

TRAUMATIC SYNOVITIS

Four patients who had acute traumatic synovitis were treated by means of intra-articular injection of 37.5 milligrams of hydrocortisone acetate. Relief of pain and swelling appeared to be much more rapid than in comparable patients treated by such measures as rest in bed, use of analgesics, and application of cold packs or pressure bandages. Further trial of this method of treatment is indicated.

PSORIATIC ARTHRITIS

Hydrocortisone acetate was injected into the distal interphalangeal joint of the great toe of one patient who had psoriatic arthritis and into both knees of another patient afflicted with the same disease. In all three instances, temporary improvement took place in the synovial reaction of the injected joint, comparable to the improvement noted in patients who had rheumatoid arthritis.

GOUT

A severe attack of acute gouty arthritis of the knee took place in one patient who had tophaceous gout. Two days after onset of this attack, 37.5 milligrams of hydrocortisone acetate was injected into the knee. Little improvement was noted for twenty-four hours, but rapid regression of the attack occurred within the next four days.

TRAUMATIC OLECRANON AND PREPATELLAR BURSITIS

Seventeen patients who had prepatellar bursitis and six who had olecranon bursitis were treated by injection of hydrocortisone acetate; follow-up studies in these patients lasted for more than five months. The cause of the bursitis in all cases was assumed to be trauma, since no evidence of infection was present in any. In addition, fifteen patients gave histories of specific injury to the region of the bursa prior to the onset of symptoms.

Local anaesthesia was used in some of these cases. Almost all the fluid was aspirated from the bursa in seventeen cases, while either no fluid or an insignificant amount was removed in the others. The amount of fluid aspirated was as much as sixty cubic centimeters in two cases. The amount of hydrocortisone acetate injected varied from 12.5 to 37.5 milligrams. The time of maximal response to treatment ranged from one to fourteen days. The interval from the onset of symptoms until the institution of treatment varied from one day to seven months.

Of the seventeen patients who had prepatellar bursitis, fifteen (88 per cent.) experienced complete and, to date, lasting remissions. In one of these, however, additional trauma after several weeks resulted in recurrence of the bursitis. This recurrence also responded promptly to injection and the patient has remained well. Failure of treatment occurred in two patients, who did not respond at all to the injection; the bursae in these patients were excised surgically.

Of the six patients who had olecranon bursitis, five responded well and permanently to the injection of hydrocortisone acetate. Treatment failed in one patient, and the bursa was excised.

The dosage of hydrocortisone acetate did not appear to have any proportionate effect either on the rate and amount of the reduction of swelling or on the relief of pain, provided that the amount given was at least 12.5 milligrams. The duration of bursitis before treatment had no apparent bearing on the effectiveness of this treatment. It appeared to make no difference in most instances whether or not the bursa was aspirated at the time of injection. The size of the bursae began to reduce in twenty-four to forty-eight hours after injection and became normal within seven days. Pain and swelling subsided entirely within forty-eight hours in those cases in which treatment was successful; the symptoms have not recurred.

EPICONDYLITIS (TENNIS ELBOW)

In view of the favorable anti-inflammatory response noted in other conditions, it had been our hope that injection of hydrocortisone acetate might be efficacious in the treatment of epicondylitis (tennis elbow). After ten months of use of this treatment and follow-up studies of at least six months, however, it appears that the results are not permanent. Of thirteen patients treated by means of injections of hydrocortisone acetate, only two secured complete and lasting relief of symptoms. Two additional patients stated that they had 75 per cent. relief of pain and tenderness; one patient, who had incomplete relief after one injection, was relieved of symptoms after a second injection, but the result is still indeterminate, since only two months have elapsed since the last treatment.

If 75 to 100 per cent. permanent relief of symptoms is considered to be a satisfactory result, only 38 per cent. of these patients obtained such results. Seven of the thirteen patients were relieved of pain from one to five months after the injection of hydrocortisone,

only to have recurrence of symptoms; in some the recurrent symptoms were not so severe as formerly, but in others they were just as severe. One patient failed to secure even temporary relief. This patient was unable to avoid trauma to the region involved—her arm—since she is forced to use crutches for walking; it is considered that this continuation of the irritating factor accounted for the complete lack of benefit.

The usual method of treatment in this group of patients was to inject procaine hydrochloride into the region and then to inject 25 to 37.5 milligrams of hydrocortisone acetate.

OSGOOD-SCHLATTER DISEASE

Each of two patients who had Osgood-Schlatter disease received an injection of 37.5 milligrams of hydrocortisone acetate into the affected region. Favorable response took place in both patients, with complete remission of swelling, pain, and tenderness within six weeks, a shorter period than is expected after other forms of treatment. One of these engaged in a track meet three months after treatment and won three events.

SUMMARY AND CONCLUSIONS

A study has been made of the results after local injections of hydrocortisone acetate (compound F acetate) in the treatment of some common orthopaedic conditions. In the treatment of rheumatoid arthritis, marked improvement was noted in the condition of 49 per cent. of the injected joints, whereas improvement was moderate in 35 per cent. and mild in 13 per cent.; no relief was obtained in 3 per cent. of the joints into which this material was injected. The relief of symptoms persisted for two to eight days in most cases. When improvement was more prolonged, some additional factor usually was present; among the more important of these was general improvement in the status of the rheumatoid arthritis, either spontaneous or induced by other forms of treatment. Brief systemic effects were noted in 21 per cent. of the patients who had rheumatoid arthritis and who received injections of hydrocortisone acetate. Intra-articular injection of hydrocortisone acetate appears to be a helpful adjunct in the treatment of rheumatoid arthritis, especially in patients who have involvement of only a few joints or in whom other measures of treatment are generally adequate except in a few joints.

Marked improvement occurred in 38 per cent. of the injected joints in patients who had osteo-arthritis; moderate improvement was noted in 34 per cent., mild in 7 per cent., and insignificant in 21 per cent. The improvement usually lasted for one to eight days; when more prolonged improvement was noticed, other factors, such as increased rest and limitation of weight-bearing activities, appeared to play a role. This form of treatment apparently is helpful as an adjunct in the management of osteo-arthritic patients, particularly those suffering from acute or subacute flare-ups or those in whom maximal application of other conservative measures has failed to relieve discomfort.

Limited experience with intra-articular injection of hydrocortisone acetate in the treatment of traumatic synovitis, psoriatic arthritis, and acute gouty arthritis suggests that its temporary antirheumatic effect might be helpful in the management of these conditions. Use of hydrocortisone acetate in the treatment of epicondylitis (tennis elbow) has proved discouraging to date.

The most favorable response to local treatment by injection of hydrocortisone acetate apparently occurs in self-limited conditions, such as traumatic bursitis. Injection of hydrocortisone acetate appears to hasten the recovery and shorten the period of convalescence.

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DISCUSSION

Dr. Lenox D. Baker, Durham, North Carolina: Dr. Young and his associates have used compound F in Osgood-Schlatter disease with relief of symptoms and apparent early recovery. From the results presented in the paper, from reports of other clinics, and from what has been seen in our experience, it appears that hydrocortisone acetate, when used in cases with a local synovial reaction, can bring about a rather dramatic improvement. If the etiological factor in the synovial change is recurrent in nature, it appears that we can expect recurrence of symptoms. The results reported here from the use of compound F in osteo-arthritis coincide with this impression. The authors apparently have found it necessary to put the joints at rest; this in turn removes the cause of the synovial reaction. In addition they have found that, when the patients continue to use the involved joint, recurrence can be expected.

Dr. Young in his presentation of the results in tennis elbow reported only one patient who did not benefit. The other twelve were definitely benefited. Seven of the twelve were relieved of discomfort for one to five months. It should be kept in mind that it is necessary to remove the cause of the disease; the drug acts only on the secondary changes in the synovial membrane.

Dr. Goldner pointed out that contradictory results have been reported in rats, rabbits, and dogs. He feels that one should be cautious in evaluating clinical use of the drug on the basis of the results seen in animal experiments. The observations of Dr. Goldner and his coworkers appear to show that the compound has its greatest effect on the peritendinous structures and little or no effect on the intrinsic healing and maturity of tendon repair. This is further evidence that the drug is active in preventing fibrositis in highly vascularized tissues. Dr. Goldner's studies suggest the development of the local use of this drug or one of its derivatives. Such use would eliminate the side effects seen when the drug is used systemically.

Dr. J. Albert Key, St. Louis, Missouri: We first operated on arthritic patients who were being treated with cortisone—mostly patients with bunions or needing reconstructive procedures of the feet—and noticed that they had a much smoother convalescence and that their wounds healed normally. Later we read reports about delays in wound healing caused by hydrocortisone. At the same time we used cortisone in hand surgery and in tendon surgery in order to prevent postoperative swelling and adhesions. We thought that the results were very good and that the wounds healed normally. It is difficult, however, to determine whether or not results would have been good without cortisone. In looking over past experience, one is apt to forget failures and remember only good results.

We then studied the effect of cortisone on the healing of experimental fractures in rats[8] and found that we could not tell the difference, grossly or microscopically, between animals which had had cortisone

and those which had not. We then used it in the peritoneal cavity. We produced adhesions with talc and found that there were fewer adhesions in the animals treated with cortisone. In Dr. Goldner's experiment, there was only one animal in which the tensile strength was tested at or after twenty-one days and was found to be approximately the same in both instances; it would seem that one should not hesitate to translate the conclusions from these experimental results into clinical practice because, while cortisone apparently may delay healing and the formation of scar tissue, its principal activity—the inhibition of formation of fibroblasts—appears to take place during the first two weeks. At the end of that time, apparently, it has very little effect and healing proceeds normally. Certainly we have used it with safety clinically and will continue to do so.

In the use of compound F in various orthopaedic conditions discussed by Dr. Young and his coworkers, the most brilliant results were obtained in acute conditions of the shoulder, with or without calcification.

In some of the severely painful shoulders with swelling of the hands and crippling we have done a stellate-ganglion block, with injections of compound F into the bursa performed at the same time; some of these patients have experienced a remarkable cure.

Dr. Young was not discouraged about the use of compound F in hypertrophic arthritis. It is important that the drug be injected into the joint cavity and this may be difficult in a hip with a degenerative condition and a tight capsule. In these cases, flexing the hip to relax the anterior portion of the capsule may be helpful. We think that this treatment has done the patients with knee and hip conditions a great deal of good; and we have also used it in the ankle. The treatment has been used in traumatic conditions; our experience with traumatic prepatellar bursitis has been similar to that of the authors. Some of our patients with radial tenosynovitis, painful heels, and tennis elbow have had relief; others have not been relieved.

Compound F has also proved very valuable in postoperative joint conditions, especially in knee joints with effusion and considerable pain. We aspirate the joint and inject compound F, and our experience has been that the patient has a smoother convalescence after this injection. Not infrequently we have injected compound F immediately after closing the joint. We do not consider the injection an operating-room procedure. We even inject hip joints in the office; in such cases we administer novocain first and we have not found that the novocain has done any harm.

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Dr. Leo Mayer, New York, N. Y.: I should like to bring out one point which I feel Dr. Goldner has not emphasized sufficiently. I assume from the illustrations that most of the tendons used were Achilles tendons. In dealing with the Achilles tendon, one is not dealing with a true sheath. It differs very markedly, for instance, from the sheaths of the flexor tendons of the hand and foot. There is a fibrous layer, a fascial envelope surrounding the tendon, and from the fascial envelope numerous fine bands extend from the fascia into the sheath. When one is dealing with the sheath of a flexor tendon, on the other hand, the tendon lies free inside a cavity which is lined by a tissue very similar to the synovial membrane of a joint. The cells are flattened and have the appearance of endothelial cells. There are no fibrous bands extending from the sheath to the tendon. The question is, then, is the effect of cortisone the same when we are dealing with a sheath of this type as the reaction of the fascial envelopment of the Achilles tendon. It is the true type of sheath in which we as hand surgeons are particularly interested.

Dr. Young (closing): We did not have time to present all the conditions in which compound F acetate has been used. We had two patients with gouty arthritis who responded to the drug, in both of whom an acute flare-up subsided rapidly, and two patients with Osgood-Schlatter disease who improved considerably within twenty-four to forty-eight hours and whose pain and swelling disappeared entirely within a few weeks. One of my patients was able to win three events in a track meet six weeks after the injection and has had no further difficulty with the Osgood-Schlatter disease. The shoulder, we feel, offers a special problem. At present we are reviewing the status of patients with shoulder lesions.

The postoperative use of compound F acetate is of benefit. I have used it after removal of the medial meniscus and particularly after a patellectomy. I inject it usually during the third week, when it is desirable to start motion. The patients seem to recover motion more rapidly and with less pain than do those in whom the drug is not used. This, however, is merely an impression and we are not yet able to substantiate it.

Dr. Goldner (closing): It should be emphasized again that the use of cortisone in conjunction with tendon surgery in uncomplicated situations is not desirable. The drug has been given to patients undergoing tendon surgery, but no conclusions can be drawn from these, because the number of cases is small and there is no control series. The drug is certainly not a substitute for meticulous surgery.

Dr. Mayer has pointed out that the tendon sheath around the Achilles tendon in dogs is not a true synovial sheath. That is correct. When, in cutting the tendon, the fascial envelope around the Achilles tendon was punctured but otherwise not disturbed, there was a moderate fibrous reaction during the healing process. In the usual tendon injury it is necessary to remove either the fascial envelope or the synovial sheath—whichever surrounds the tendon—in order to obtain a satisfactory mobilization and repair of the tendon. The sutured tendon is usually left exposed and the effect of cortisone on the subsequent formation of fibrous tissue then becomes evident.

A FEMUR WITH TWO HEADS AND NECKS

A Case Report

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Adequate roentgenographic studies prior to reconstructive hip surgery are mandatory. They are required for the selection of the surgical procedure of choice. They also may obviate the necessity for further surgical intervention. A case in point follows:

The patient was a seven-year-old Puerto Rican boy (Figs. 1-A, 1-B, and 1-C) who was sent to our Orthopaedic Clinic on October 20, 1952, by his school physician, because of a limp on the left side.

Past history revealed that at one and one-half years of age, while in Puerto Rico, this child fell and sustained an injury to his left hip. He was taken to a hospital where an inflammatory process of the hip was treated by incision and drainage. He was hospitalized for nine months. Following this period of hospitalization, the child resumed normal activities and has never had any further difficulty with the exception of a limp. The parents had known of the child's limp for several years but had not previously sought medical advice.

Physical examination revealed a well developed, well nourished seven-year-old boy who walked with a

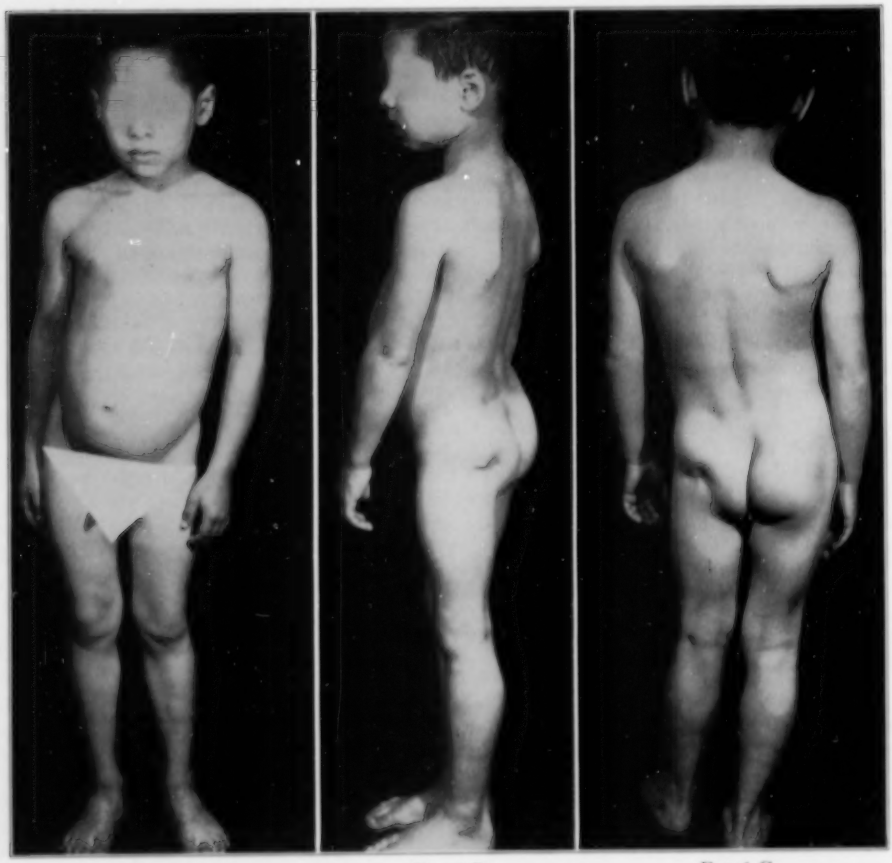

FIG. 1-A FIG. 1-B FIG. 1-C

Front, side, and back views of seven-year-old Puerto Rican boy with dislocation of the left hip, secondary to an old septic arthritis.

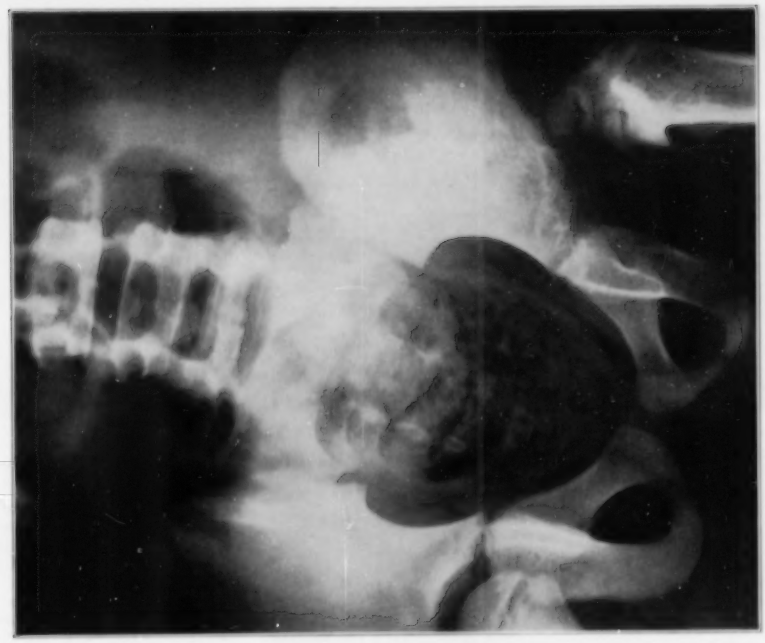

FIG. 2-B

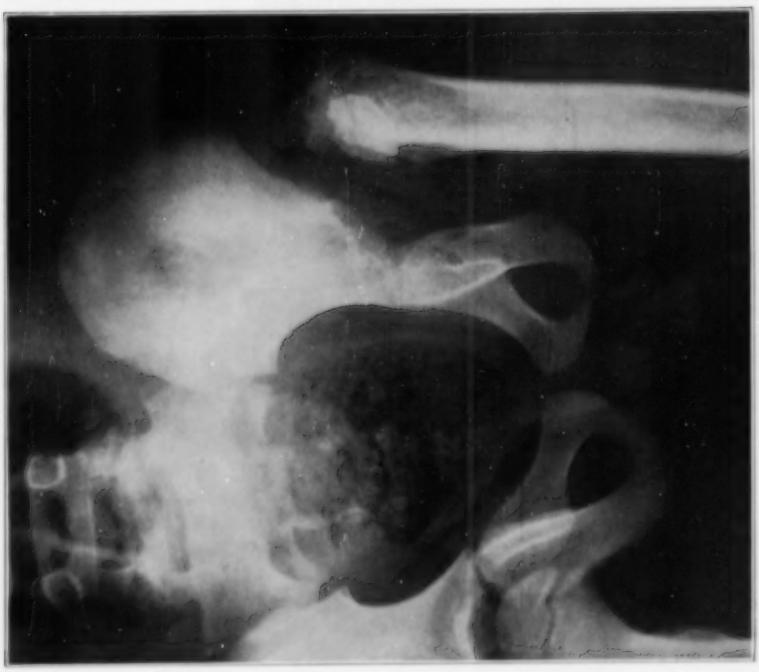

FIG. 2-A

Roentgenograms demonstrate a small amount of telescoping. The manual push-pull technique with x-ray control was used.

FIG. 2-C

Fig. 2-C: This preoperative roentgenogram is almost a true lateral view of the hip. It does not reveal the abnormal condition which was first discovered on the postoperative roentgenograms.

FIG. 3-A

Fig. 3-A: This postoperative roentgenogram, with the patient still in plaster, first demonstrated the presence of two heads and necks on the femur. The osteotomy of the greater trochanter can be seen.

left "short-leg" gait and a moderate lurch to the left. The Trendelenburg test on the left was not conclusive. With a block measuring one and three-quarter inches under the left foot, the pelvis became level. Clinical measurement from the anterior-superior iliac spine to the medial malleolus was twenty-two and one-half inches on the right and twenty-one inches on the left. Knee-to-ankle lengths were equal, ten inches. There was a deep, puckered, one-inch scar over the middle of the left buttock and another at the mid-medial aspect of the left thigh. Both were well healed, non-tender, and were not adherent to the deeper structures. The top of the greater trochanter on the left side could be palpated above its normal level. Actual telescoping could not be elicited.

In the supine position, the left lower extremity assumed a position of external rotation of approximately 45 degrees. Flexion at the hip was complete and painless. There was no flexion contracture, and hip extension was possible to 180 degrees. There was no internal rotation. External rotation was to 90 degrees as compared with 60 degrees on the right side. Adduction and abduction were normal, 45 degrees. The physical examination showed no other abnormal findings. The laboratory studies, including urine analysis, hemogram, sedimentation rate, and serological tests were normal. Roentgenograms of the chest were normal.

Roentgenographic examination of the pelvis showed a poorly developed acetabulum and femoral head and neck on the left side. The upper femoral shaft was displaced widely outward and upward, the head of

the femur apparently resting against the iliac wing. Push-pull roentgenograms (Figs. 2-A and 2-B) revealed vertical instability, but the tip of the femur could not be brought down to the level of the acetabulum.

The presumptive diagnosis was dislocation of the left hip, secondary to an old infectious arthritis.

It was decided to apply skeletal traction preliminary to performing a Colonna type of reconstruction [1], as is used for congenital dislocation of the hip, to gain stability. On October 22, 1952, a Kirschner wire was inserted in the supracondylar region of the left femur and was incorporated in a long plaster cylinder. Traction was applied through the Kirschner wire and fourteen pounds of weight was gradually added. After ten days of traction, the upper limit of the femur was at the level of the acetabulum; a Colonna hip reconstruction was performed at that time.

A Colonna type of incision was used; the greater trochanter was osteotomized and reflected proximally with the attached abductors. The capsule was removed from the attachment to the iliac wing, without exposing the femoral head. The acetabulum was found to be filled with fatty fibrous tissue which was removed; then the acetabulum was deepened with reamers. It was not deemed necessary to strip the capsule from the femoral head and neck. Several mattress sutures were then used to close the capsule over the femoral head. On reduction of the hip, there seemed to be an excess of capsule on the superior aspect of the femoral neck. However, it did not seem to block the reduction, and, with the hip held in mild abduction and internal rotation, stability seemed good. Following closure of the incision, the long plaster cylinder (with the incorporated Kirschner wire) was integrated into a single hip spica. The hip, maintained by plaster, was in flexion of approximately 15 degrees, abduction of 20 degrees, and internal rotation of 20 degrees.

Postoperatively, traction was re-established by means of the Kirschner wire. On the first postoperative day, portable x-rays gave the impression that the femoral head was not engaged in the acetabulum. Traction was increased and two days later roentgenograms revealed the appearance of two distinct femoral heads and necks, the lower head being in good relation to the acetabulum (Fig. 3-A).

Traction was maintained for five weeks, after which the spica and Kirschner wire were removed. Active motion and pool therapy were instituted. Clinically, the hip felt stable, and the boy was allowed to walk with crutches. Although the left lower extremity was short, he was not permitted a shoe lift in order to try to establish a mild abduction contracture which would help to compensate for the limb-length inequality.

The patient was discharged two months after the operation, at which time he was walking well with the aid of crutches. The hip was stable both clinically and roentgenographically, and frequent examinations showed increasing range of motion.

The patient was last seen five months after operation. At that time he walked well, with and without crutches, but still demonstrated a short-leg gait. The lurch on walking was much less than that observed

FIG. 3-B

This first roentgenogram of the hip out of plaster shows the pathological entity more clearly.

FIG. 4-A

Roentgenogram demonstrates the small range of abduction at five months after open reduction. Increase in abduction seemed to be blocked by the upper head and neck abutting against the superior rim of the acetabulum.

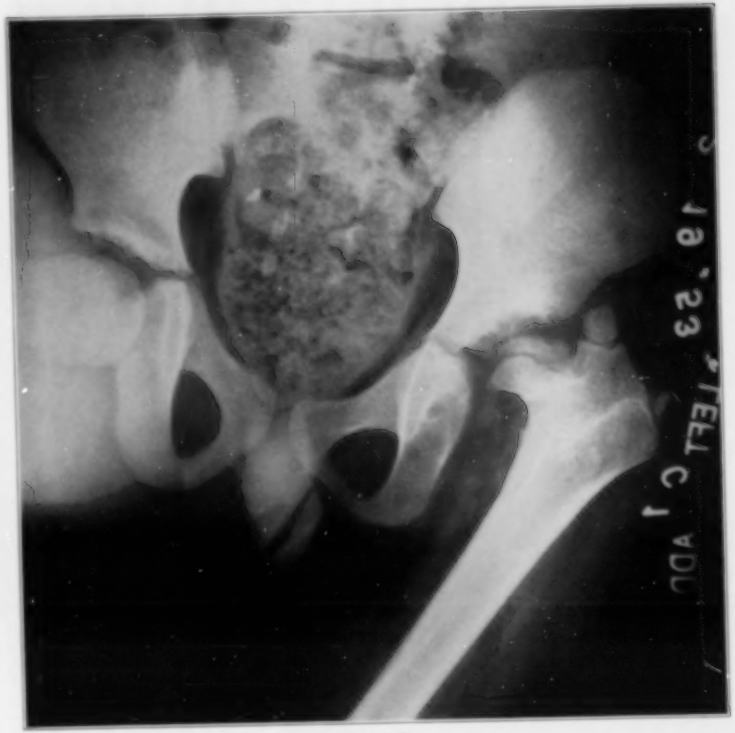

FIG. 4-B

Roentgenogram demonstrates good adduction without loss of stability.

FIG. 5-A

FIG. 5-B

FIG. 6

Fig. 5-A: Roentgenogram of the hip at five months after reduction with the extremity held in internal rotation, clinically estimated to be 20 degrees.

Fig. 5-B: Roentgenogram of the hip five months after operation with the extremity held in external rotation of 15 degrees.

Fig. 6: Roentgenogram made five months after operation, demonstrating a true lateral view of the hip joint with apparently satisfactory relationships.

preoperatively. The stability was good. The Trendelenburg test was positive. The hip had attained painless ranges of motion from 90 degrees flexion to 175 degrees extension, from 30 degrees abduction to 30 degrees adduction, from 20 degrees internal rotation to 15 degrees external rotation. Roentgenograms (Figs. 4-A, 4-B, 5-A, 5-B, and 6) showed excellent relationships in all ranges of motion, but it seemed possible that the upper femoral head and neck were blocking further abduction. Measurements of limb lengths at this time produced only a one-inch discrepancy as compared to a preoperative discrepancy of one and one-half inches.

It is interesting to speculate as to the pathogenesis of this unusual structural entity. Assuming that the diagnosis of old septic arthritis was correct, we believe that the central portion of the upper femoral epiphyseal plate had been destroyed during the active infectious process. Subsequently, with further growth, two separate femoral heads and necks developed. Dislocation probably occurred at this time or shortly after weight-bearing was resumed.

In retrospect, had roentgenograms of the hip in internal and external rotation been taken, the pathological entity would have been discovered preoperatively and our postoperative embarrassment would have been avoided. The extreme rarity of the condition helps to explain our failure to recognize it; we know of no other reported case.

In having placed the lower femoral head into the acetabulum, the more developed and normal looking of the two heads was unknowingly selected. It was anteverted almost 90 degrees in relation to the upper femoral head; this can now be demonstrated even in the anteroposterior preoperative film (Figs. 2-A and 2-B). It has been suggested that, if the upper femoral head had been placed into the acetabulum, additional length would have been gained.

At present, the functional and roentgenographic results seem quite satisfactory. It has been suggested that, possibly, one head may have to be removed. More time must elapse for adequate follow-up and evaluation of the operative procedure.

1. Colonna, P. C.: An Arthroplastic Operation for Congenital Dislocation of the Hip—A Two Stage Procedure. Surg., Gynec., and Obstet., **63:** 777–781, 1936.

DISCUSSION

Fracture Healing after Fixation

(*Continued from page 587*)

healed, and microscopic sections may disclose islands of dead bone which are incorporated in the living bone. How is it replaced? I don't know. I've never been able to figure out the mechanism of creeping replacement of compact bone. But the point is, if you get union, you do not get any shortening and you do not need to make pressure to compensate for resorption. Another point is, will pressure on these two dead bone ends of cortical bone, provided you can maintain it, stimulate bone formation in the cartilaginous callus and membranous bone which are uniting the two fragments and stimulate bone production beneath the periosteum and in the callus? I don't know. I haven't been able to prove it, but we think we have proved in our work that it is not so much the method you use as the man behind the method. If you have a good surgeon, he can get good results by any of the three methods, provided he has the apparatus. If you have a poor surgeon, you can give him the best apparatus in the world, and he will still get a high percentage of failures.

THE PATHOGENESIS OF IDIOPATHIC SCOLIOSIS

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The distinction between the underlying mechanical factors and the basic pathological process has been consistently kept in mind throughout the author's studies of scoliosis; this has proved to be a fruitful approach to the problem of determining the pathogenesis of idiopathic scoliosis.

It has been shown that human gait not only causes physiological scoliosis but that it also plays a paramount role in the initiation and development of paralytic scoliosis [8, 9]. Gait seems also to be decisive in the aggravation of scoliosis following thoracoplasty, as will be demonstrated in a forthcoming study. Moving pictures taken of children with idiopathic scoliosis clearly show the marked increase in deformity during locomotion. If one accepts the concept that the pathological process underlying idiopathic scoliosis is essentially a diminished resistance of the spinal column to compression and rotation and recognizes that these forces are enormously increased during gait, it might be stated with some certainty that the mechanical factor bringing about all forms of acquired scoliosis is gait [8].

The pathological process has been traced by comparing the physiological lateral movements of the spine with those observed in structural scoliosis. It has been stated in earlier studies that in structural scoliosis the vertebral column penetrates into the space surrounding it, regardless of the simultaneous movements of the head, shoulder girdle, trunk, and pelvis. During physiological movements, the spine moves simultaneously and in conformity with these parts of the body; in structural scoliosis, however, the spine moves by itself, penetrates the space surrounding it, and becomes so firmly established, especially in the thoracic region, that no movement or manoeuvre can release it. Although the body is capable of carrying out movements which produce a number of the signs of true scoliosis, such movements eventually lead to physiological scoliosis only. Physiological scoliosis is invariably present in man from the age of five, and steadily increases throughout life [8].

Scoliosis has four roentgenographic characteristics:

1. *Penetration* occurs in the frontal plane. It may be defined as the lateral slipping of the spine into the thoracic cavity or into the pelvic space. It is characterized by the difference between the distance of the spine from the axillary line of the chest wall or of the pelvic rim, or both, on the convex side as compared with that on the concave side of the curve. This distance is less on the convex side than on the concave side. No method of therapy, even when the spine has been straightened, has so far abolished or even markedly diminished the factor of penetration; the spine still remains in the half of the thorax toward the convex side of the curve and in the pelvic space on the convex side.

Penetration is a rather complex displacement of one or more vertebrae. The penetrating vertebrae enter the space surrounding them, pulling with them a number of the vertebrae above and below. The penetrating vertebrae frequently assume a "staircase" or "step" relationship to each other; such a relationship indicates the site where the slipping into the thoracic or pelvic space took place (Figs. 19-E and 19-F). Penetration sometimes not only appears to be a lateral dislocation or subluxation of one or two vertebrae, but is in fact just that, since the displacements exceed physiological limits. Displacements do not occur alone in the apophyseal joints; lateral slipping or penetration also occurs through the partial separation of the vertebrae from the discs and of the

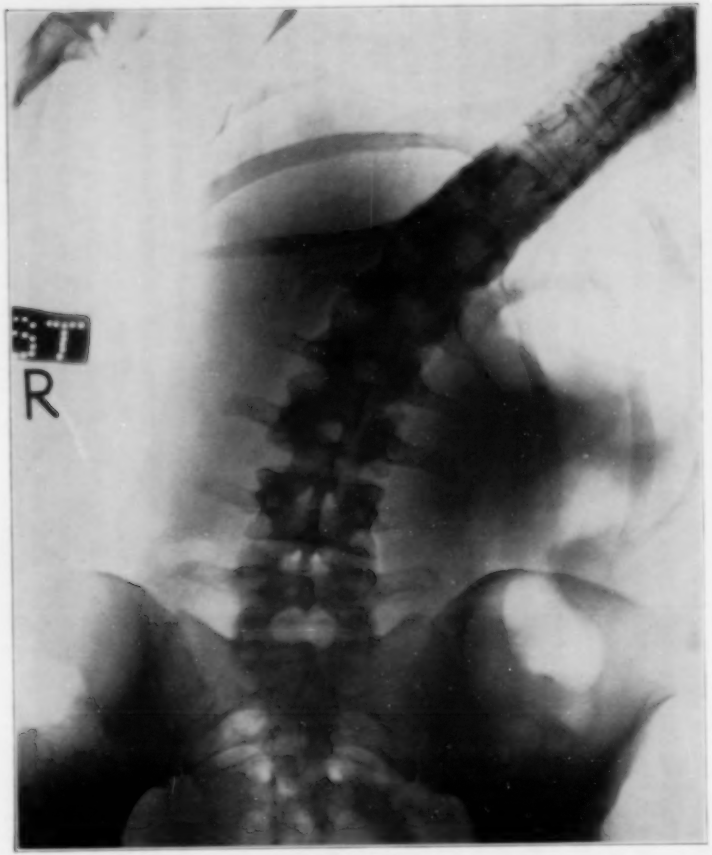

FIG. 1-A

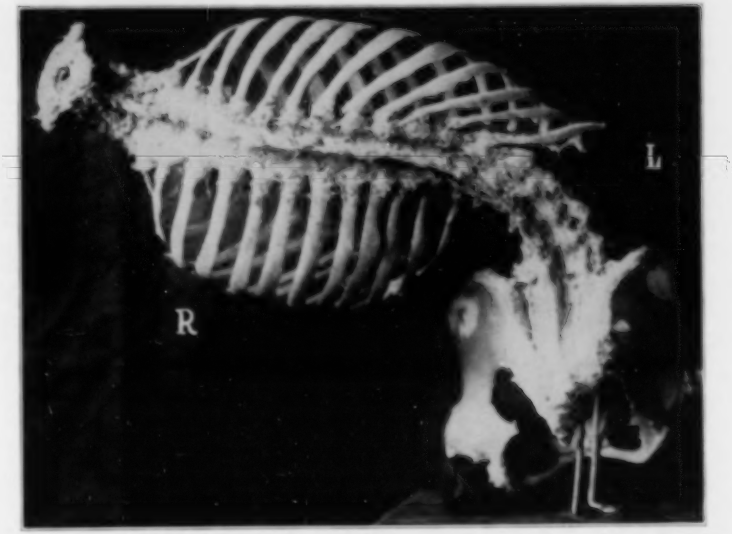

FIG. 1-B

Fig. 1-A: Roentgenogram of the spine of a ten-year-old child bending to the left. Note the rodlike appearance of the thoracic spine. Lateral movement takes place from the twelfth thoracic vertebra to the third lumbar vertebra. The first, second, and third lumbar vertebrae are in convex rotation, which is indicated by the spinous processes deviating to the left side.

Fig. 1-B: Specimen from a scoliotic girl of unknown age. Contracture of the spine with the thoracic segment in rodlike lateral movement is shown. The etiology of the scoliosis is unknown; it is presumably neurogenic. There is no evidence of rotation of the trunk and pelvis, or of penetration of the spine.

Fig. 2-A: Roentgenogram of the spine of an eight-year-old child. The trunk is rotated to the left, and there is rotation of the spinous processes to the right which is indicated by the shift of the articular facets to the right. Note the narrowing of the chest on the right and the penetration of the normal spine into the thoracic cavity.

Fig. 2-B: Roentgenogram of the normal spine of a nine-year-old child. The pelvis is rotated to the left; this movement is accompanied by the rotation of the spinous processes to the right which is indicated by the deviation of the spinous processes and the shift of the articular facets to the right. Note penetration of the normal spine into the right side of the thorax.

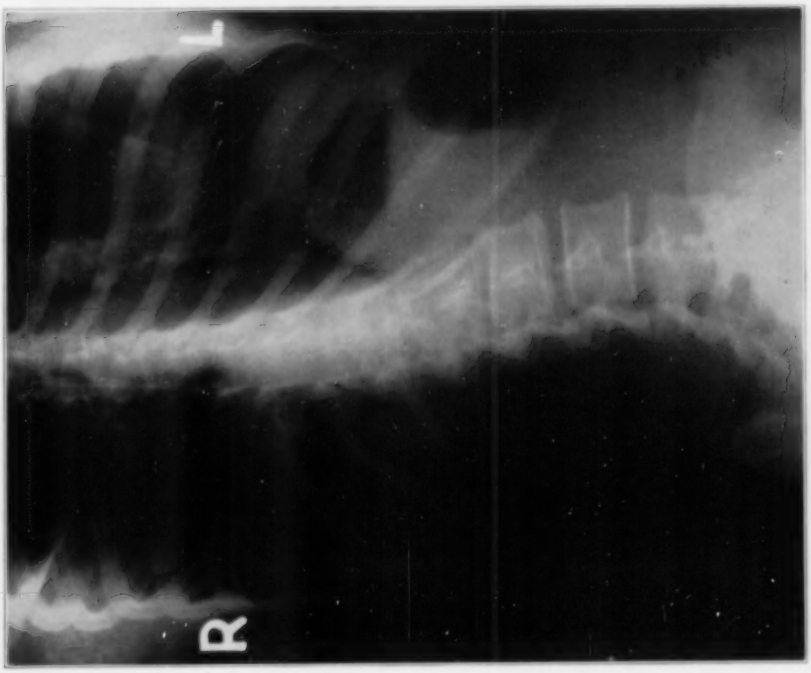

FIG. 2-B

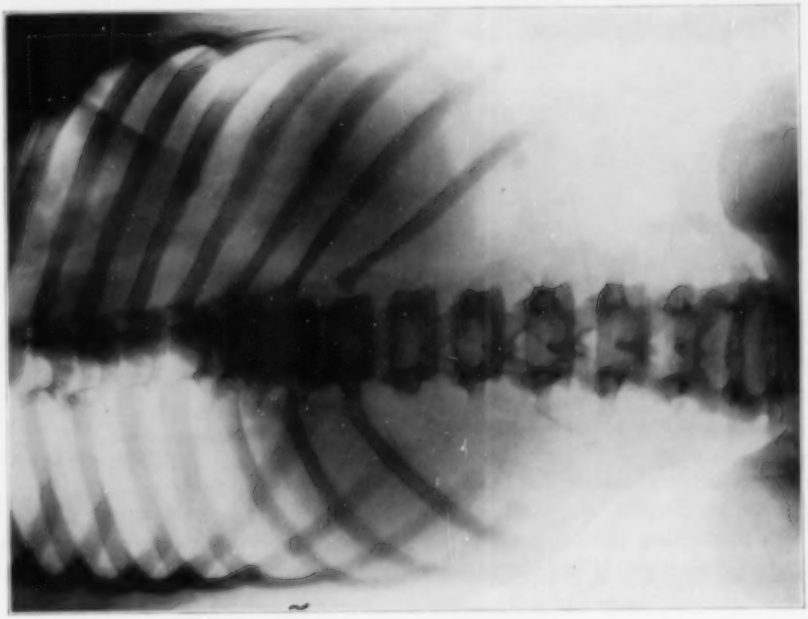

FIG. 2-A

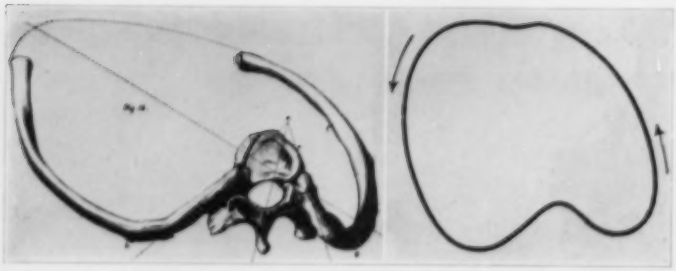

FIG. 3-A FIG. 3-B

Fig. 3-B shows the rib ring from a normal thorax rotated in the direction of the arrows. The compression of the thorax on the convex side and its enlargement on the concave side should be noted. This is similar to the condition shown in the scoliotic rib ring in Fig. 3-A. [Fig. 3-A is reproduced from Taf. IV, Fig. 16, *Pathologie und Therapie der seitlichen Rückgratverkrümmungen (Scoliosis)* von Adolf Lorenz. Wien, Alfred Hölder, 1886. Fig. 3-B is reproduced from *Über Bedingungen und auslösende Momente bei der Skoliosenentstehung (Versuch einer funktionellen Skoliosenlehre)* von Aladár Farkas. Stuttgart, Ferdinand Enke Verlag, 1925.]

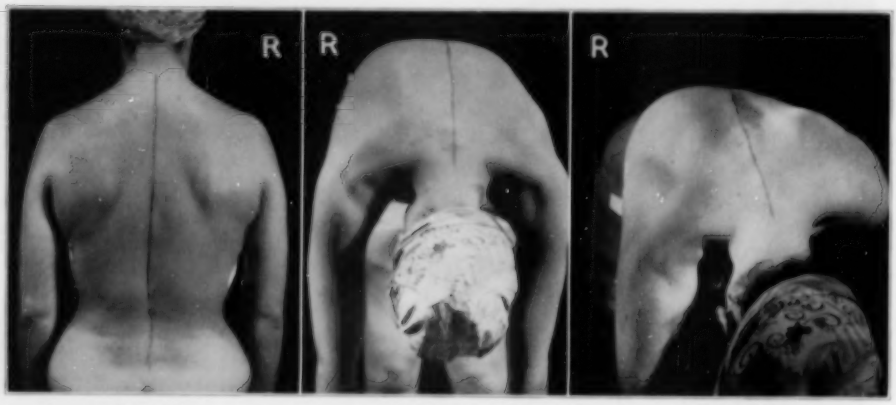

FIG. 4-A FIG. 4-B FIG. 4-C

Photographs of a young woman with a normal spine. It should be noted that bending with rotation of the trunk to the left produces a "scoliotic" hump on the right side (Fig. 4-C).

vertebral body from the epiphyseal ring. Simultaneously, torsion of the vertebral ends of the ribs occurs on the convex side and there is flattening of the ribs on the concave side. Thus penetration is intervertebral as well as intravertebral.

2. *Articular contracture* in lateral deviation involves the capsule and the ligaments of the apophyseal joints. It is the factor most accessible to correction. Capsular contracture is a more or less prominent restriction of physiological movement.

3. *Rotation* of the vertebrae must be recognized as distinct from the rotation of the shoulder girdle, thorax, and pelvis, and will be discussed later in this paper*.

4. *Compression* of the vertebrae on the concave side of the curve has so far proved to be inaccessible to any method of treatment.

The two characteristics which practically defy any correction, penetration and compression, are, roughly speaking, the basic traits of idiopathic scoliosis.

There are no muscles which can bring about either the penetration or its release. The factors preventing the spine from penetrating the surrounding space are essentially of a passive nature. It has been found that this passive mechanism is represented by:

* Lateral deviation of the thoracic spine is, for anatomical reasons, not possible without simultaneous rotation. The two movements should have been discussed under one heading; however, since rotation of the vertebrae can be carried out independently of simultaneous lateral deviation, the two are discussed separately.

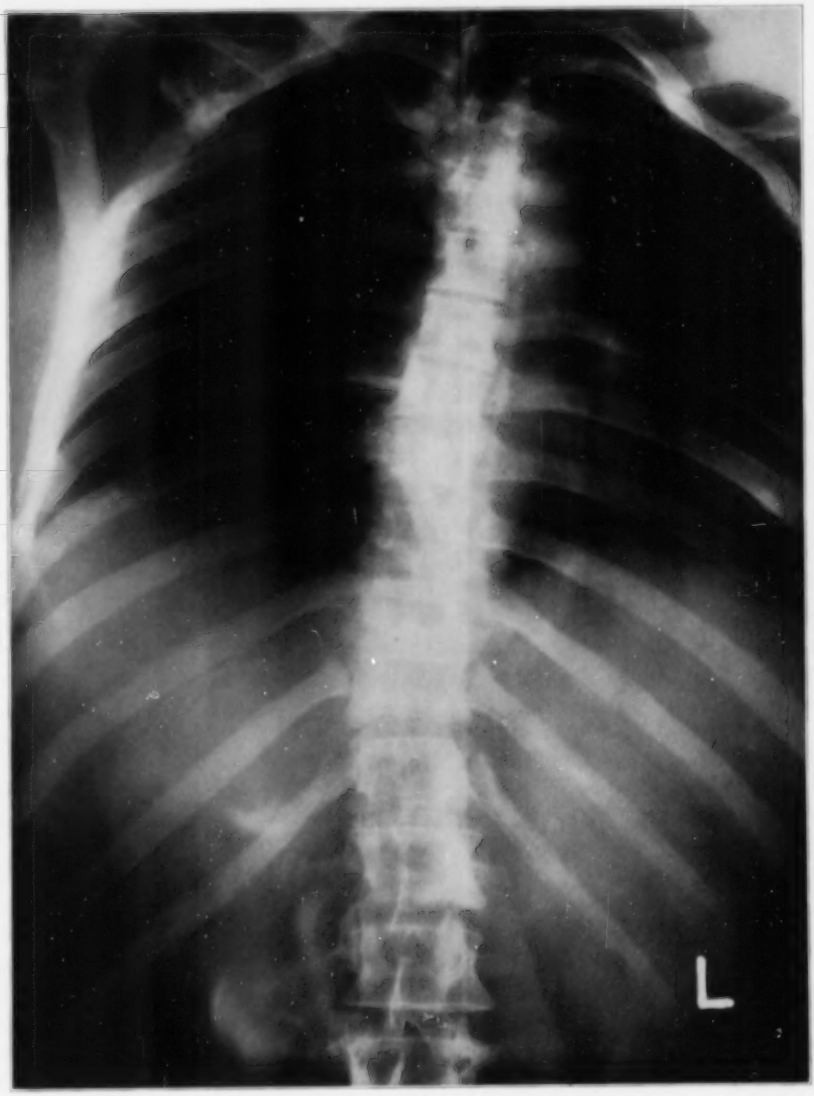

FIG. 5-A

Roentgenogram of the spine in a young man with right thoracolumbar idiopathic scoliosis.

1. The ligamentous apparatus and the discs;
2. The ribs of the thoracic spine;
3. The nearly sagittal position of the articular facets in the lumbar spine;
4. The physiological sagittal curves, the curve in the lumbar region being more efficient than that in the thoracic;
5. The inertia of the vertebral bodies, for they are kept in the sagittal plane by body weight.

The role of the ribs in the prevention of penetration is well demonstrated by two observations. Feiss noticed that in true lateral bending the thoracic spine behaves, from the age of five on, like a rod with almost no movement between the individual vertebrae. The author has confirmed this observation but has found segmental lateral movement

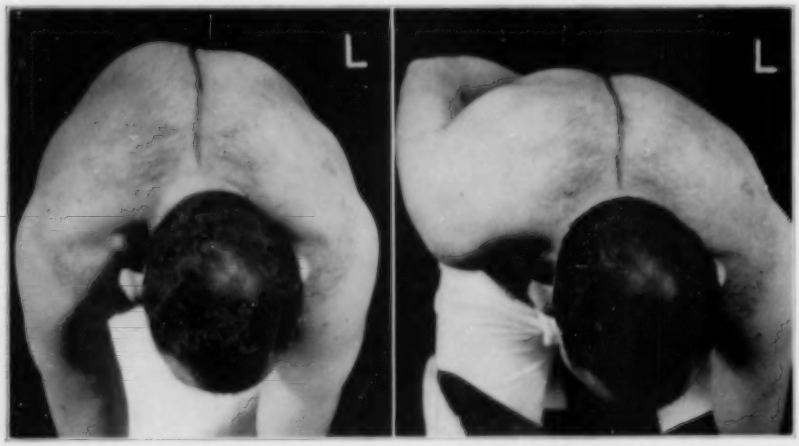

FIG. 5-B FIG. 5-C

Fig. 5-B: In this photograph it is shown that bending brings out the hump on the right side.
Fig. 5-C: Bending combined with rotation of the shoulder girdle and of the trunk to the right (toward the convexity) makes the hump disappear. Lateral deviation of the spine is corrected by the same movement.

from the eighth thoracic vertebra upward to be present shortly after birth. Later more and more vertebrae participate in segmental lateral movement until, about the age of six (except in not too rare individual variations), the thoracic spine hardly possesses any intervertebral movements and behaves as a solid piece. Lateral bending takes place at the thoracolumbar juncture where the ribs are short (floating ribs). The ribs, therefore, cannot block the excursion of the vertebrae at the thoracolumbar juncture as they do in the rest of the thoracic spine (Fig. 1-B).

Another observation is the effect of resection of the ribs in thoracoplasty. Thoracoplasty is invariably accompanied by scoliosis with the convexity to the side of the rib resection, regardless of the surgical method employed.

In scoliosis following poliomyelitis, the extreme relaxation of the ligamentous apparatus, the softening of the discs, and the decreased muscle tone are the pathological process which the author terms *paralytic spine*. The paralytic spine precedes scoliosis, but it is not necessarily followed by scoliosis, as has been shown in an earlier publication [9]. The relaxation of the ligament-disc system is followed by the disappearance of the lumbar lordosis. The deformity may be initiated by highly asymmetrical weight-bearing during walking, standing, or sitting. It is easy to prove that no scoliosis develops until weight-bearing, especially walking, is resumed. The extreme forms of rotation preceding lateral deviation and the lack of vertebral compression are the main characteristics of this form of acquired scoliosis.

Among the *physiological* movements capable of producing some of the signs of scoliosis are rotation of the shoulder girdle, of the trunk, and of the pelvis. Rotation of the spinous and articular processes is in the opposite direction to rotation of the shoulder, trunk, and pelvis; thus, rotation of the trunk to the right is accompanied by rotation of the neural arch to the left, and the rotation of the pelvis to the left is accompanied by the rotation of these structures to the right (Figs. 2-A and 2-B). No curve results, but the thoracic spine temporarily penetrates the thoracic cavity. The ribs on the side opposite that toward which the rotation of the trunk takes place become sharply curved and form a thoracic hump (Figs. 3-A and 3-B). In healthy persons with a normal spine, a "scoliotic" hump can be produced by means of this movement (Figs. 4-A, 4-B, and 4-C). Moreover, in scoliotic patients with a right convex thoracic curve rotation of the trunk and shoulder girdle to the right brings about the decrease or even the disappearance of

the hump on the convexity. The same holds true for the lumbar spine where pelvic rotation may bring about or efface this clinical sign of scoliosis (Figs. 5-A through 6-D).

FIG. 6-A

Roentgenogram of the spine in a young woman with left idiopathic scoliosis of the lumbar spine.

FIG. 6-B FIG. 6-C FIG. 6-D

Fig. 6-B: Bending brings out the hump on the left side of the lumbar spine.

Fig. 6-C: Bending combined with rotation of the pelvis to the left (toward the convexity) makes the hump disappear.

Fig. 6-D: Bending combined with rotation of the pelvis to the right (toward the concavity) increases the hump.

FIG. 7

Roentgenogram showing the shape of the apophyseal joints of a thoracic vertebra was made with pieces of lead snugly pressed into the four joint surfaces.

The resistance of the thoracic spine to intervertebral movements is caused chiefly by the ribs. Rotation of the trunk, however, bends the ribs in all three planes and allows intervertebral movements (Figs. 2-A and 2-B). The thoracic spine rotates, but it does not move laterally. The shape of the intervertebral articulations explains this phenomenon. They are not flat surfaces inclined anteriorly but are curved, so that they may rotate or move on one another in an anteroposterior direction (Fig. 7).

The articular facets in the lumbar spine are roughly in the sagittal plane. The facets of each lumbar vertebra embrace the facets of the vertebra above from the lateral side (Figs. 8-A and 8-B). Lateral movement starts with the closing of the facets on one side and the simultaneous separation of the facets on the opposite side. This amounts to initial rotation of the lumbar spine, and it is followed by the ascent of the superior facet along the inferior facet on one side and the simultaneous descent of the superior facet along the inferior facet on the opposite side. Thus, in the lumbar spine, lateral movement is connected with rotation, notably with physiological convex rotation (Fig. 1-A) [20, 25, 26].

The facets are not exactly in the sagittal plane, for the inferior facets diverge. The degree of divergence, termed *obliquity of the facets*, in large measure determines the degree of rotation during lateral bending. Thus, if the inferior facets were more oblique, the gap

FIG. 8-A

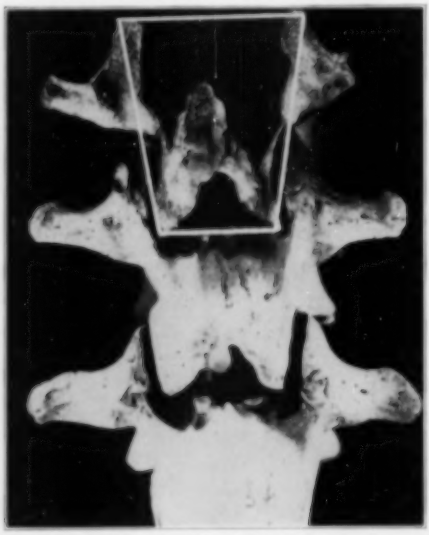

FIG. 8-B

Fig. 8-A: Photograph of specimen shows lumbar vertebrae in physiological lordosis. There is a minimal gap between the corresponding facets.

Fig. 8-B: Photograph of specimen shows lumbar vertebrae in physiological kyphosis. It should be noted that the divergence of corresponding facets creates a gap which allows greater rotation.

between the facets facing each other would grow wider, and the rotation, accompanying lateral bending, would become more pronounced (Figs. 24-A and 24-B).

In addition to the degree of obliquity, the degree of lumbar lordosis determines the amount of rotation. During flexion the superior facets mount along the inferior facets on both sides simultaneously. Since the inferior facets are oblique, the gap between the corresponding facets becomes wider and the ability to rotate is greater with increasing flexion. Thus, the two factors, the degree of obliquity of the inferior facets and the degree of lordosis of the lumbar spine, account for the amount of rotation (Fig. 8-B).

Rotation is intimately connected with penetration during the later stages of idiopathic scoliosis. In all forms of paralytic scoliosis, however, rotation without penetration and lateral movement is present in the beginning, and rotation always precedes lateral deviation. Unfortunately such an early "prescoliotic" stage in idiopathic scoliosis is not known to the author.

The factor of compression on the concave side, as previously stated, is one of the two fundamental characteristics of idiopathic scoliosis. It has been regarded as an inherent characteristic of the deformity from the time of the earliest investigations [16]. Yet it is not completely correct to regard it so. In the lumbar form of idiopathic scoliosis, vertebral compression does not develop, if it develops at all, until about the fifth decade of life. Until that time, the compression of the lumbar intervertebral discs on the concave side is the only compression phenomenon; the compression of the vertebrae on the concave side is largely confined to the thoracic spine.

This observation necessarily leads to the division of idiopathic scoliosis into two well defined types:

1. The *thoracic type* with initial compression;

2. The *lumbar type* with initial rotation, which may be followed by compression. This distinction will be qualified later in this paper.

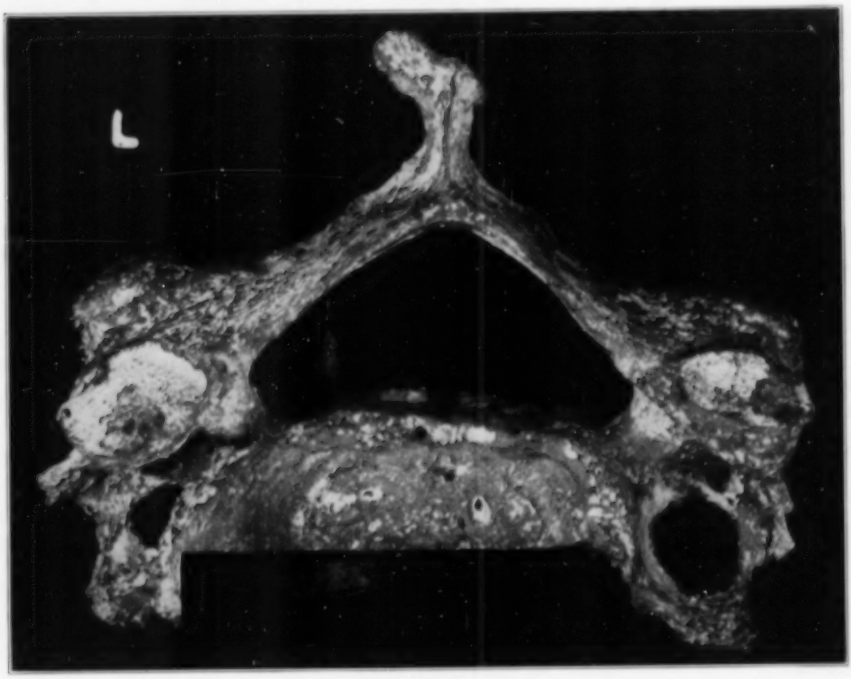

FIG. 9-A

Specimen of the seventh cervical vertebra from a left high thoracic curve. The scoliotic deformation of the neural arch and of the vertebral foramina should be noted.

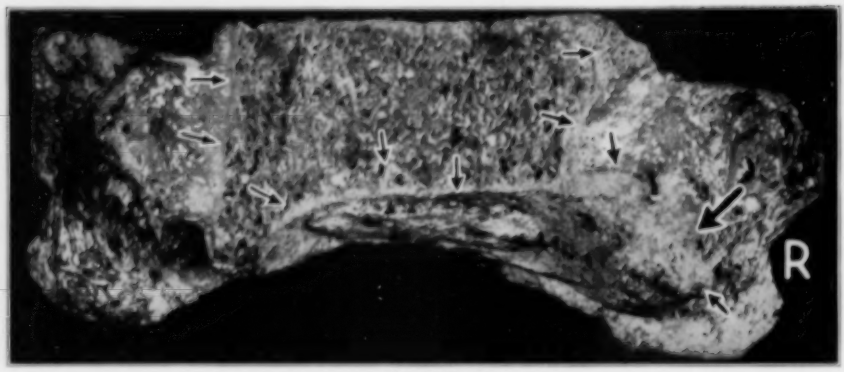

FIG. 9-B

Frontal section of the seventh cervical vertebra shown in Fig. 9-A. Arrows indicate the displacement to the right of the epiphyseal ring and the remnants of a longitudinal slit at both sides of the vertebra. The slit on the right side is continuous with the line of separation between the epiphyseal ring and the cortical shell. The compression of the vertebral body on the right should be noted.

FIG. 9-C

Drawing of the frontal section of the seventh cervical vertebra shown in Fig. 9-B illustrates the displacement of the epiphyseal ring to the right.

There is also a *combined type*, in which both etiological factors (the factor leading to lumbar rotation and that leading to thoracic compression) are present simultaneously from onset. The combined type is the most serious as regards prognosis.

COMPRESSION

In healthy bone, increased pressure produces osteosclerosis (condensation). Hence, unilaterally increased pressure is necessarily followed by the formation of denser bone on the side of the increased pressure. Healthy bone does not give way under pressure; it reacts to pressure with an increase of width of the bony trabeculae and a decrease in the spaces between them. Under certain pathological conditions, the bone on the side of increased pressure yields for a while, but the formation of denser bone which follows later sets a limit to unilateral compression. This may be observed in rickets, in Paget's disease, and in other conditions [27].

Compressibility is apparently the result of the temporary inability of the bone to form denser trabeculae as compression increases. If increased density does not occur, compression is followed by such collapse as is seen in senile osteoporosis or in destructive processes.

The vertebrae have the capacity to withstand the enormous pressures acting on them.

FIG. 10-A

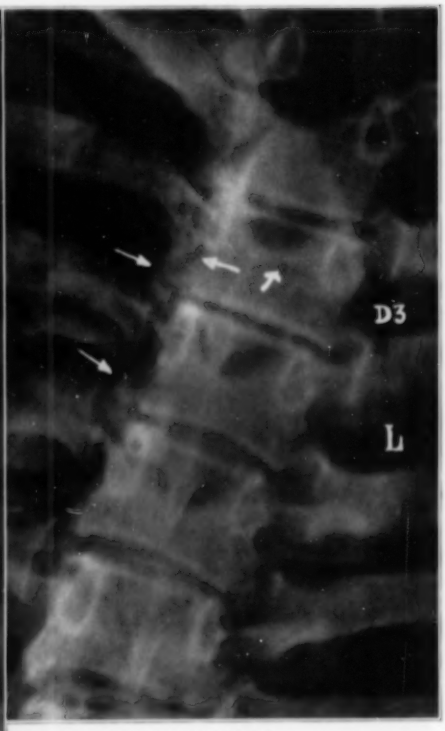

FIG. 10-B

Figs. 10-A and 10-B: Roentgenograms of the spine in a sixteen-year-old girl show a left high thoracic and a right thoracic scoliosis. Large portions of the epiphyseal ring are displaced to the right. The concavity of the high thoracic curve is at the level of the third and fourth thoracic vertebrae. In Fig. 10-B, the arrows indicate the displaced epiphyseal ring. At this level, the slit between the displaced epiphyseal ring and the channel crossing the third thoracic vertebra frontally are continuous.

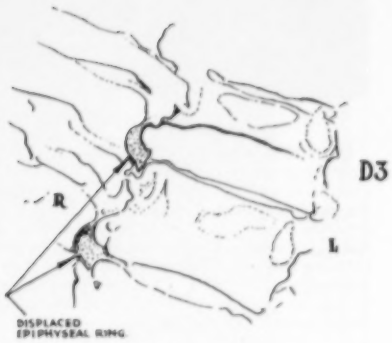

FIG. 10-C

Fig. 10-C: Drawing illustrates the displaced epiphyseal ring.

The disc, with the nucleus pulposus, the cartilaginous plate, the end plates, and the vertebral cortex (compact shell), coupled with the so-called epiphyseal ring, are the structures which counteract compression before it involves the intravertebral system.

The weakest link in this system is the epiphyseal ring [1, 21]. The epiphyseal ring develops from the cartilaginous plate and fuses with the rest of the vertebra, including the upper and lower bony surfaces of the vertebra, the end plate of the vertebra, and the vertebral cortex enveloping the vertebral body, around the age of twenty-five.

Until the epiphyseal ring has fused with the vertebra, it is so loosely attached along the circumference of the vertebra that it can easily be separated from it [1]. The intervertebral disc is intimately connected with the epiphyseal ring by means of Sharpey

Fig. 11-A

Fig. 11-B

Figs. 11-A and 11-B: Roentgenograms of the spine in a nineteen-year-old girl show a right thoracic and a left lumbar idiopathic scoliosis. In Fig. 11-B, at the right (convex) side of the sixth thoracic vertebra, it is to be seen that the line of separation between the partially displaced epiphyseal ring and the right border of the vertebra is continuous with the channel crossing the vertebral body frontally. (This is shown diagrammatically in Fig. 11-C.) All vertebrae from the sixth thoracic to the eleventh thoracic clearly show the channels which cross them frontally at their middle.

Fig. 11-C

fibers, with the result that in all movements of the growing spine there is a potential danger that the attachment of the epiphyseal ring with the compact structures of the vertebra may be harmed.

Evidence will be produced to show that the separation of the epiphyseal ring from parts of the vertebral cortex on the one hand and of the vertebral cortex from the interior of the vertebral body on the other form the basic pathological process of idiopathic scoliosis of the thoracic spine. The separation of the epiphyseal ring may assume forms of actual slipping (Figs. 9-A through 12-B). The latter is naturally limited because the disc, intimately connected with the epiphyseal ring, keeps the epiphyseal ring fairly securely in place or sets it back again through its enormous resilience during the first three decades of life. It has also not uncommonly been found that separation or failure of fusion only concerns the connections of the epiphyseal ring with the vertebral cortex.

FIG. 12-A

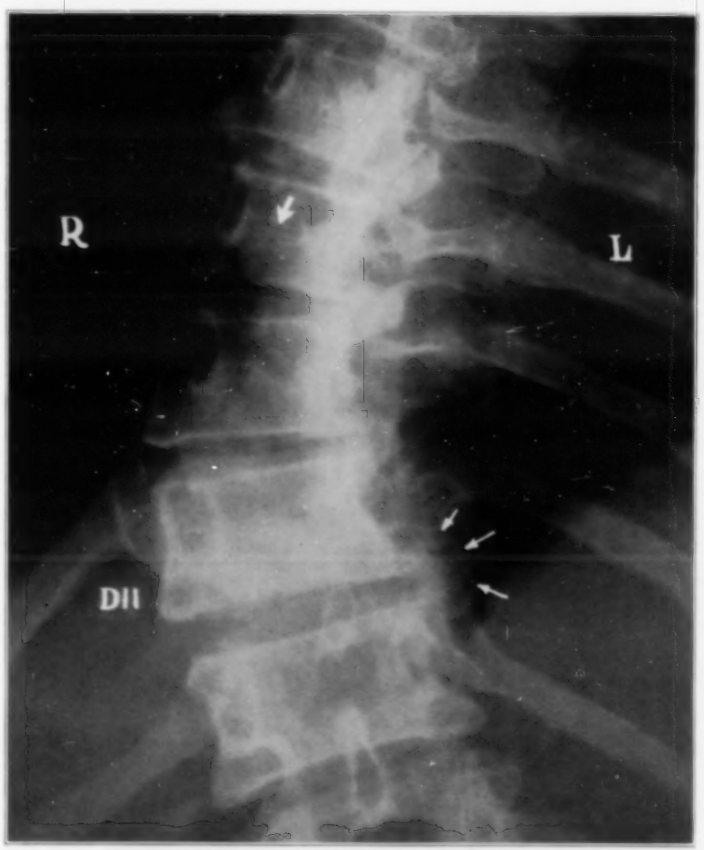

FIG. 12-B

Roentgenograms of the spine in a woman, forty-seven years old, show a right thoracic and left lumbar idiopathic scoliosis. Atrophy is generalized. Between the eleventh and twelfth thoracic vertebrae (on the concave side of the curve), large portions of the calcified epiphyseal ring are extruded (arrows). At the ninth thoracic vertebra, there is a persistent shadow of a channel crossing it frontally.

The separation of the vertebral body cortex from the internal cancellous structures is preceded by a number of phenomena which together constitute the predisposing causes of idiopathic scoliosis in the thoracic region. This predisposition, coupled with the mechanical factor of weight-bearing, brings about the scoliotic deformity of the thoracic spine. The former is the predisposing factor to the development of the deformity and the latter, induced by weight-bearing and walking, is the exciting or mechanical cause.

In order to understand the pathological process underlying idiopathic scoliosis, dissections of the vertebrae in all segments of the spine have been undertaken. The vertebrae

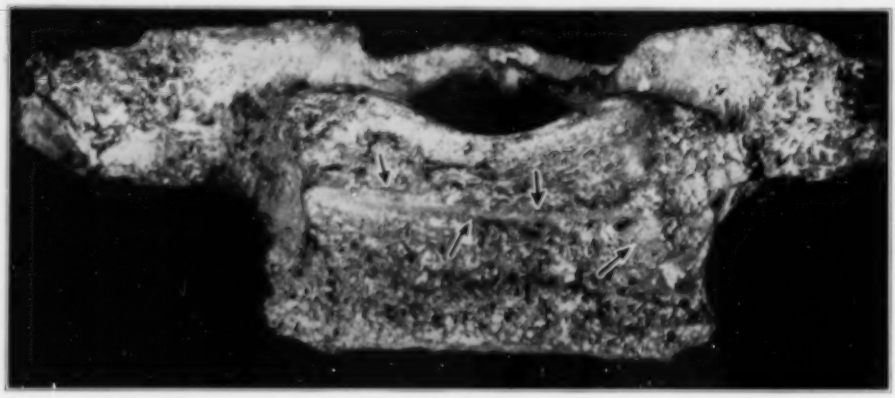

FIG. 13-A

Figs. 13-A, 13-B, and 13-C: Frontal sections of adult vertebrae.

Fig. 13-A: Frontal section of a cervical vertebra. Note at the juncture of the upper and middle thirds a bony bar crosses the cancellous structures horizontally (arrows). Such cross bars are not rare in the other segments of the spine.

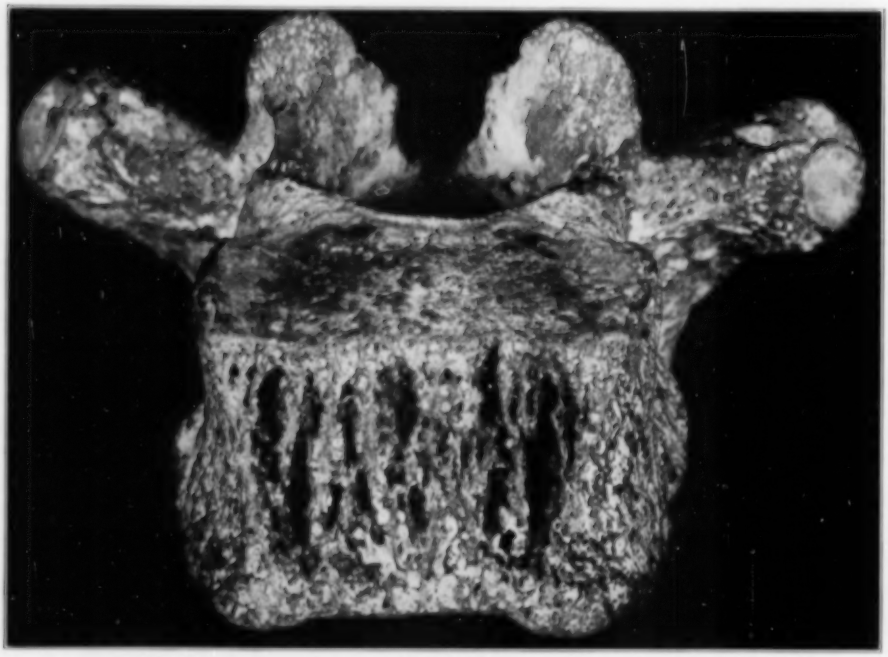

FIG. 13-B

Frontal section of a thoracic vertebra.

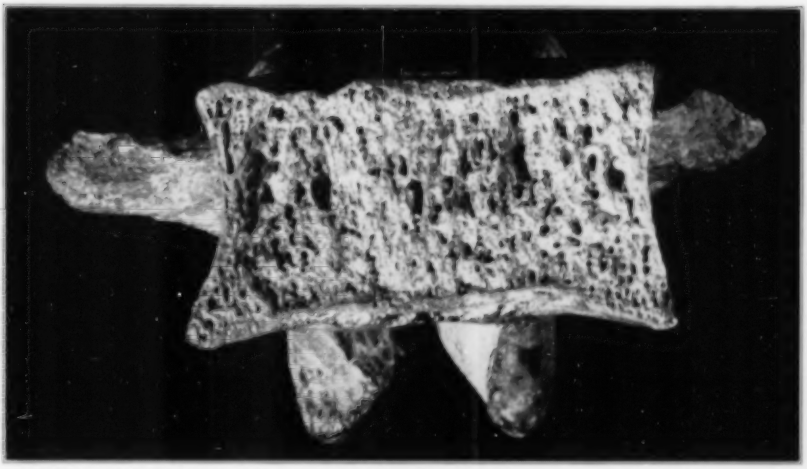

FIG. 13-C
Frontal section of a lumbar vertebra.

have been cut through frontally, sectioned at different depths, and examined macroscopically and by means of roentgenograms. Vertebrae of three different ages were examined: macerated vertebrae from an adult with the epiphyseal ring preserved, macerated vertebrae from a five-year-old child (the cartilaginous epiphyseal ring was naturally dissolved during the maceration), and the vertebrae from a newly born infant with the cartilaginous epiphyseal ring preserved.

In adult vertebrae, the epiphyseal ring, the vertebral cortex, and the end plates of both the upper and lower surfaces are intimately fused with one another and with the interior of the body. The vertebral cortex sends out strong trabeculae which connect it with the interior, with the upper and lower end plates, and with the epiphyseal ring.

By means of a light touch with a curette, the intravertebral trabecular system can be revealed. This system is differently built in the various segments of the spine.

In the cervical spine it is a very hard, sieve-like structure with very short and densely packed trabeculae. The epiphyseal ring of the upper and lower surfaces is of the same height and density. The circular shell or wall of the vertebral body is hard and thick. It is impossible to gauge the exact thickness because the transition is gradual from the walls toward the interior. This arrangement is unlike that in any other segment (Fig. 13-A).

In some instances, there is a longitudinal slit between the vertebral cortex and the trabecular system. In the anatomical specimen, this has been observed only in the cervical spine (Fig. 13-A).

In the thoracic spine, the end plate covering the upper surface is rather thin, while that covering the lower surface is two or three times as thick. The interior is formed by a great number of strong, evenly distributed, longitudinal trabeculae,—a system of strong pillars connecting the upper and lower surfaces. The lateral walls of the vertebral cortex are connected by oblique, short, and sparsely set trabeculae with the interior pillars (Fig. 13-B).

In the lumbar vertebrae, both the epiphyseal ring and the plates covering the upper and lower surfaces are of about the same width and thickness. The interior discloses a different arrangement of the trabecular system from that in the cervical and in the thoracic regions. In lumbar vertebrae, the middle third is occupied by a heavy pillar, while the two lateral thirds consist of a much thinner, abundantly interconnected, cancellous structure. This resembles lattice work except at the upper and lower lateral corners where

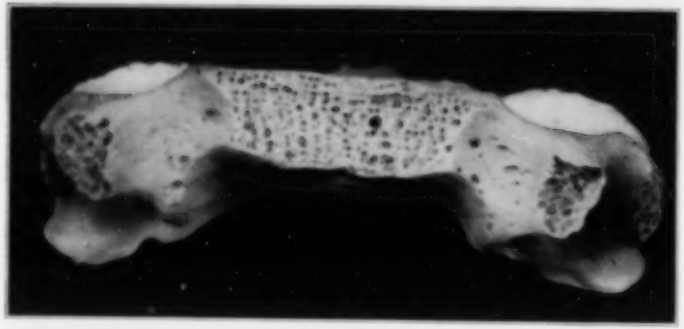

FIG. 14-A

FIG. 14-C

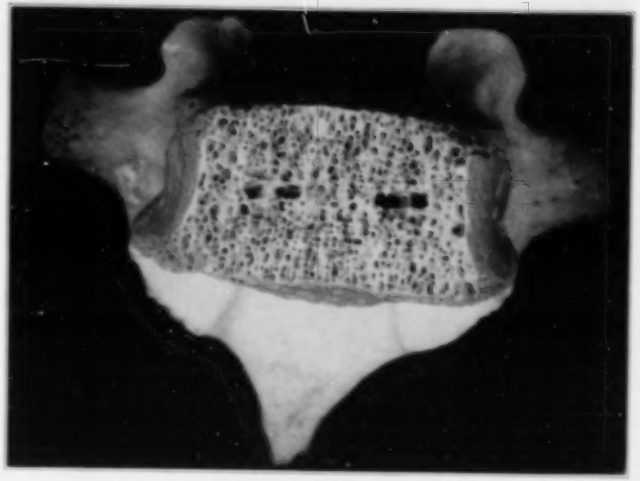

FIG. 14-B

Figs. 14-A, 14-B, and 14-C: Vertebrae from a five-year-old child.

Fig. 14-A: Cervical vertebra shows closely arranged trabeculae. The upper and lower end plates are about equal width. The vertebral cortex is solidly fused with the intravertebral structures and with the end plates.

Fig. 14-B: In the mid-portion of the thoracic vertebra are seen the remnants of a channel. The intravertebral trabeculation does not yet show the arrangement encountered in adult vertebrae. The end plates are of the same width at the upper and lower surfaces. The vertebral cortex, end plates, and intravertebral trabeculae are solidly fused.

Fig. 14-C: Section of a lumbar vertebra shows in its mid-portion a bony bar which crosses the cancellous structures horizontally (arrows). The trabeculation is not yet definitely arranged in a middle and two side pillars; however, one sees evidence to remind one of such an arrangement. The end plates, intravertebral trabeculae, and the vertebral cortex are solidly fused.

Figs. 15-A, 15-B, and 15-C: Vertebrae from a newly born infant.

Fig. 15-A: In the cervical vertebra, the ossification center is surrounded by cartilage which is equal in width in the upper and lower parts.

Fig. 15-B: In the thoracic vertebra, the ossification center is crossed by a cartilaginous bar vertically (between upright arrows). The cartilage at the upper border of the ossification center is about one third the width of the cartilage at its lower border.

Fig. 15-C: In the lumbar vertebra, the ossification center is bordered by cartilage which is twice as thick in the lower part as in the upper.

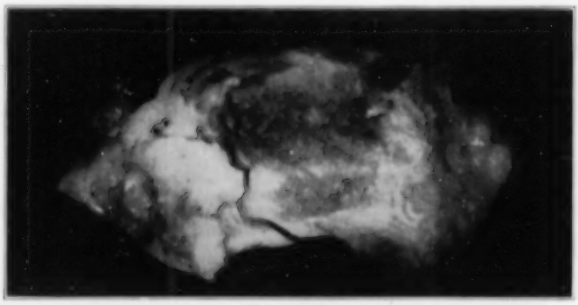

FIG. 15-A

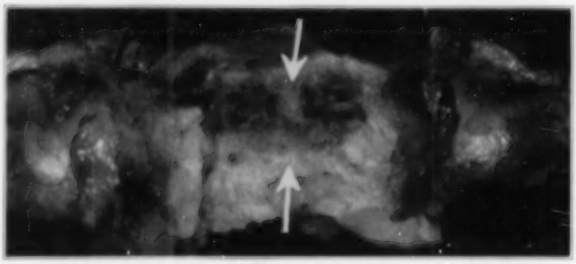

FIG. 15-B

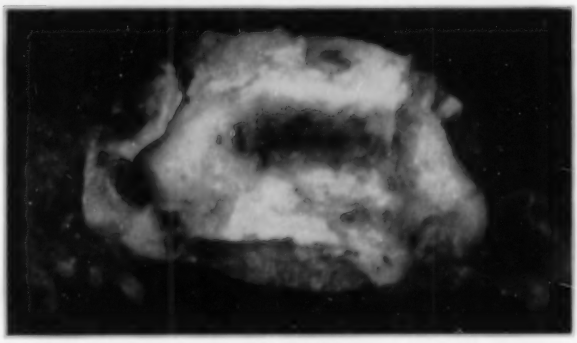

FIG. 15-C

the structure is fused with the shell by means of strong, short, and oblique trabeculae (Fig. 13-C).

In the normal spine from a five-year-old child, the intravertebral structure has not yet reached the differentiation of the adult vertebrae. Neither the longitudinal pillars of the thoracic vertebrae nor the three-pillar arrangement of the lumbar vertebrae are clearly discernible. Only the cervical vertebrae remind one of the densely woven arrangement of the intravertebral trabeculae of the adult, an observation which points to the effect of function on the development of the intravertebral structures.

The end plates, as well as the vertebral cortex, are solidly fused with the intravertebral trabeculae in all three segments. The cortex and the end plates are thin. There is not yet any difference in width between the end plates of the upper and lower surfaces (Figs. 14-A, 14-B, and 14-C).

In vertebrae of the newly born infant, there is a noteworthy difference between the width and arrangement of the cartilaginous parts of the vertebral bodies surrounding the already ossified portions. In the cervical segment, the ossified layer is relatively wide-bordered on either side by cartilage layers of about the same width (Fig. 15-A).

In the thoracic vertebrae, the caudal cartilaginous layer is three times as wide as its cephalic partner (Fig. 15-B).

In the lumbar vertebrae, the caudal cartilaginous layer is twice as wide as the cephalic layer. The already ossified middle is the narrowest in any of the segments, if it is compared with the cartilaginous layers enclosing it (Fig. 15-C).

In the normal adult vertebra there is complete fusion of the epiphyseal ring with the end plate and the cortical shell. *This unity seems to have failed in the thoracic form of idiopathic scoliosis.*

Clearly visible are lines of separation between the cortical shell and the interior of the vertebrae (Figs. 16-A, 16-B, and 16-C). The role the different arrangements of the

FIG. 16-A

FIG. 16-B

Idiopathic scoliosis in a fourteen-year-old girl. Situs viscerum inversus. The scoliotic curves are right high thoracic, left mid-thoracic, and right lumbar. From the seventh thoracic vertebra to the tenth thoracic vertebra, there is separation between the intravertebral structures and the compact shell. In the eighth thoracic vertebra, the line of separation comprising the entire epiphyseal ring penetrates the vertebral body (this is shown in the drawing, Fig. 16-C).

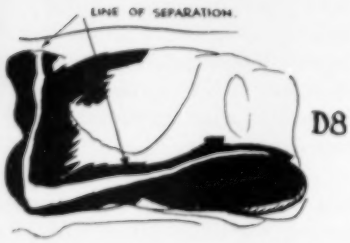

FIG. 16-C

interior of the vertebrae in the different segments play in the separation could hardly be assessed. The vertebra grows by endochondral ossification within the confines of the vertebral cortex [2, 24]. Whether the formation of the vertebral cortex during rapid growth is inadequate in scoliosis or the trabecular system connecting the shell with the interior is insufficiently formed has to be decided by examination of serial roentgenograms and dissections on a large number of cases in all ages of infancy and childhood. It is established, however, that failure of fusion or the failure of a vertebral cortex to form with sufficient strength renders the vertebra so vulnerable that the phenomena of flattening and collapse may ensue (Figs. 17-A and 17-B). The failure of fusion also causes the structures not yet properly cemented, such as the epiphyseal ring, to become displaced.

In his earlier study [8], the author showed that in physiological scoliosis almost all of the signs of idiopathic scoliosis are encountered in the skeleton. The ease of separation along the plane of apposition between the vertebral cortex (comprising the epiphyseal ring, the end plate, and the circular hull) and the internal cancellous structures of the

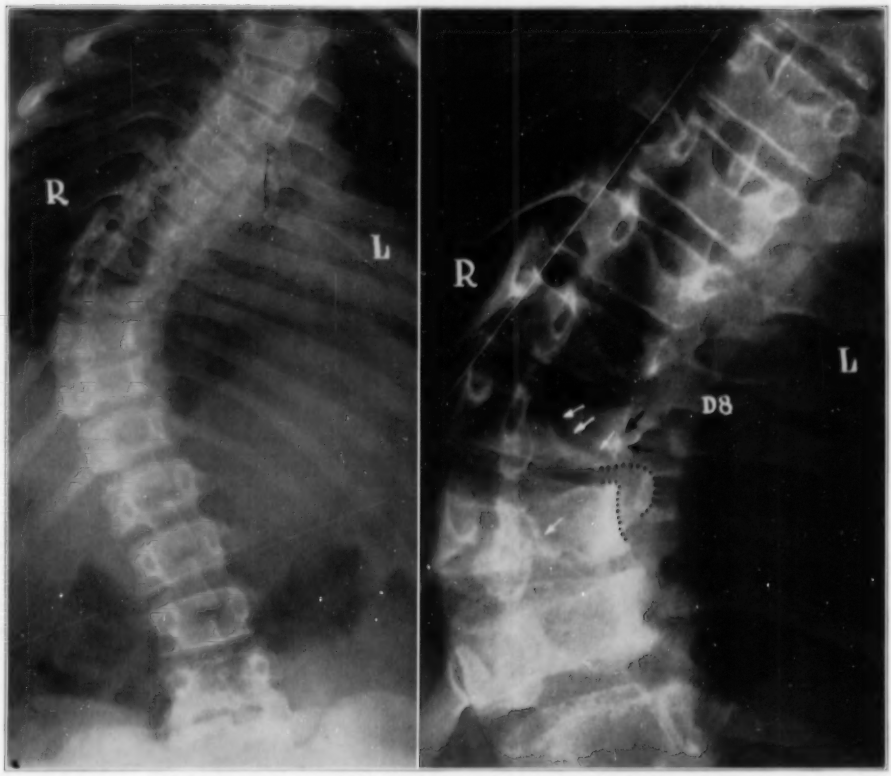

FIG. 17-A FIG. 17-B

Idiopathic scoliosis in a fourteen-year-old girl. From the eighth thoracic vertebra to the eleventh thoracic vertebra there is flattening of the vertebral bodies; the bodies are deformed and are broken into two or more parts. The epiphyseal ring of the tenth thoracic vertebra is only partially formed and portions of it are displaced to the left (dotted lines). Arrow on the ninth thoracic vertebra points out the double contour.

vertebra account for these traits. The growing child, going through the perilous stages of development, shows many signs of scoliosis. However, in the child, idiopathic scoliosis is a relatively rare occurrence. In this sense *every case of physiological scoliosis is a borderline case of idiopathic scoliosis.*

What happens under pathological conditions to force the spine into true idiopathic scoliosis will be discussed presently. The number of serial films of early cases of idiopathic scoliosis is naturally limited because the children were not seen until some abnormality had already developed. By that time the process might well have been developing for several years. The only exception to this is the infantile form of scoliosis which has been described extensively by Harrenstein. This condition is not dealt with in this treatise.

In a typical case, taken from the author's series comprising nearly 100 patients, out of which only fifteen patients had had early roentgenograms, serial roentgenograms disclosed, during the earliest stages, the development of a *high thoracic curve with its convex side toward the left.* The rest of the spine appeared fairly straight. There was as yet limited penetration of the middle and lower thoracic spine. Thus it appears that, in the early stages, a mild, high thoracic curve develops with marked convex rotation, little compression, and definite penetration, mostly into the left side of the upper thoracic cage (Figs. 18-A through 18-E). Penetration is a prognostic sign of the utmost importance and must be taken seriously, despite the fact that no involvement of the lower

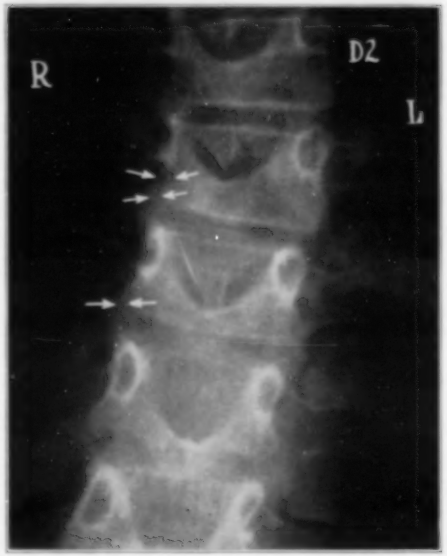

FIG. 18-A

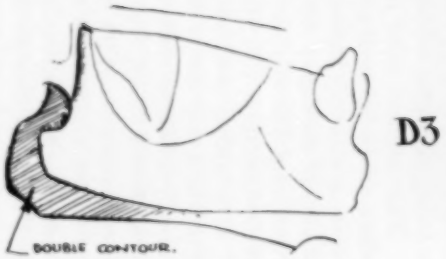

FIG. 18-B

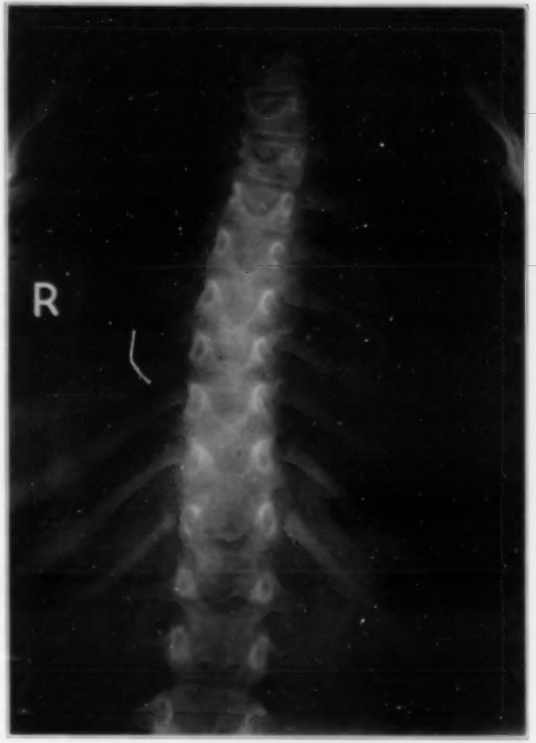

FIG. 18-C

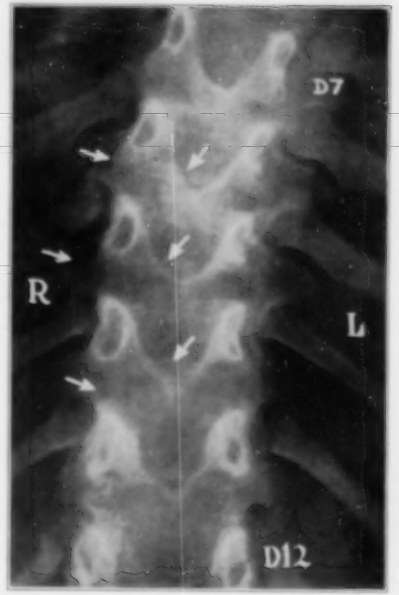

FIG. 18-D

Roentgenograms of the spine of a girl with idiopathic scoliosis at the age of four. The left curve is restricted to the high thoracic region and the spine in the mid-thoracic and lumbar regions is fairly straight without penetration and compression.

Fig. 18-A: At the second, third, and fourth thoracic vertebrae there can be seen double contours (arrows). The double contour is shown diagrammatically in Fig. 18-B.

Fig. 18-D: There is displacement of the epiphyseal rings of the eighth, ninth, tenth, and eleventh thoracic vertebrae to the right (later, the convex side of the curve). From the seventh thoracic vertebra to the eleventh thoracic vertebra the articular facets are decreased in size on the left side (later, the concave side of the curve).

Fig. 18-E: Same patient at the age of twelve. Severe form of scoliosis with compression of the seventh, eighth, ninth, and tenth thoracic vertebrae on the concave side is shown. Atrophy is present.

segments of the spine has occurred. Penetration is a constant sign and is significant, for it may give the clue to the process or processes underlying the pathological process of idiopathic scoliosis, especially if there is a marked generalized atrophy present (an infantile or juvenile form of osteoporosis with sparsely set, coarse trabeculae) (Figs. 19-A through 19-F). In the later stages of idiopathic scoliosis, the wedged vertebrae are characterized by excessive atrophy. This is not the patchy atrophy encountered in the paralytic spine; it is a generalized form similar to that in senile osteoporosis.

FIG. 18-E

Another prognostic sign (one to be seen chiefly on the concave side) is termed the *double contour;* this appears to be a longitudinal slit parting the vertebra into two uneven portions. The part on the convex side contains the bulk of the vertebral body while the part mostly on the concave side is a thin, poorly calcified structure (Figs. 17-A, 17-B, 18-A through 18-D, 19-A, 19-B, 19-G, and 19-H). Frequently one may visualize the slit as being continuous with the line of cleavage between the epiphyseal ring and the vertebral body. The slit is the line of separation of the interior of the vertebra from its cortical shell (Figs. 10-A through 11-C, 16-A through 16-C). The double contour can be seen in one or more thoracic vertebrae at the stage in which the deformity consists of the high thoracic curve only (Figs. 18-A, 18-B, 18-C, 18-D, 19-A, and 19-B). The double contour appears in the middle or low thoracic segments at the time the signs of penetration and compression start to predominate in the roentgenographic picture.

Two characteristics should be stressed: (1) that the epiphyseal ring, broken in two or more parts, is displaced not only to the convex and to the concave side but that it also penetrates the vertebral body itself (Figs. 16-A, 16-B, 16-C, 19-G, 19-H, 19-I, and 19-J); and (2) that osteoporosis seems to determine, at least partly, the degree of progression of the deformity itself. If the development of osteoporosis is halted, the progression of idiopathic scoliosis is slowed or is stopped. Thus it appears that the degree and progression of the osteoporosis, not the regional distribution of the primary curve alone as claimed by Port and by Ponseti and Friedman, largely determine the prognosis in idiopathic scoliosis.

Most of the characteristics which have been enumerated are clearly seen in routine anteroposterior roentgenograms. What is going on in the vertebrae, however, is better shown when the roentgenograms are made with the patient in the postero-anterior position. Postero-anterior roentgenograms have brought to light a number of features of the condition not otherwise clearly observed. The most conspicuous of these features is the presence of more or less broad channels crossing the vertebra frontally or obliquely or criss-crossing the entire vertebral body. It has been noted that these channels may be

FIG. 19-A FIG. 19-B

Roentgenograms show a left high thoracic curve in an eleven-year-old girl. The spine below the level of the fifth thoracic vertebra is, as yet, little involved. There is marked generalized atrophy of the spine. Parts of the epiphyseal rings of the fifth, sixth, and seventh thoracic vertebrae are displaced to the concave side (arrows in Fig. 19-B). Double contours are seen on the concave side of the curve at the fourth and fifth thoracic vertebrae.

continuous with the separating line between the components of the cortical shell and the interior of the vertebra.

In healthy persons, the presence of these channels can be visualized until the age of about fifteen. However, in healthy children these channels are surrounded by denser bone, are filled out later on, and disappear with the passing years. Fröhlich, Hahn, Hanson, and Pitzen observed channels within the vertebral body occasionally in lateral roentgenograms. Hanson showed one specimen in which frontal channels could be followed throughout the twelfth thoracic vertebra in a case of spondylitis in a five-year-old boy. He thought that these were venous channels, carrying and storing bone-marrow cells.

Whether or not the channels observed by the author are identical with those observed by Hahn and others is hard to decide. In idiopathic scoliosis, the channels are a regular occurrence, and they are encountered even beyond the age of twenty-five. The channels appear to be part of the general pathological process in the thoracic spine. Their connection with the epiphyseal ring and its line of separation has been definitely established roentgenographically in several instances (Figs. 10-A through 11-C).

Rotation of the trunk to the convex side and rotation of the shoulder girdle to the right side in a right convex thoracic curve, a movement which makes the thoracic "hump" disappear (Figs. 5-A through 6-D), showed that the *compressed vertebrae*, especially in the earlier stages, *consist of two distinct portions*. One is a porotic, although calcified, core

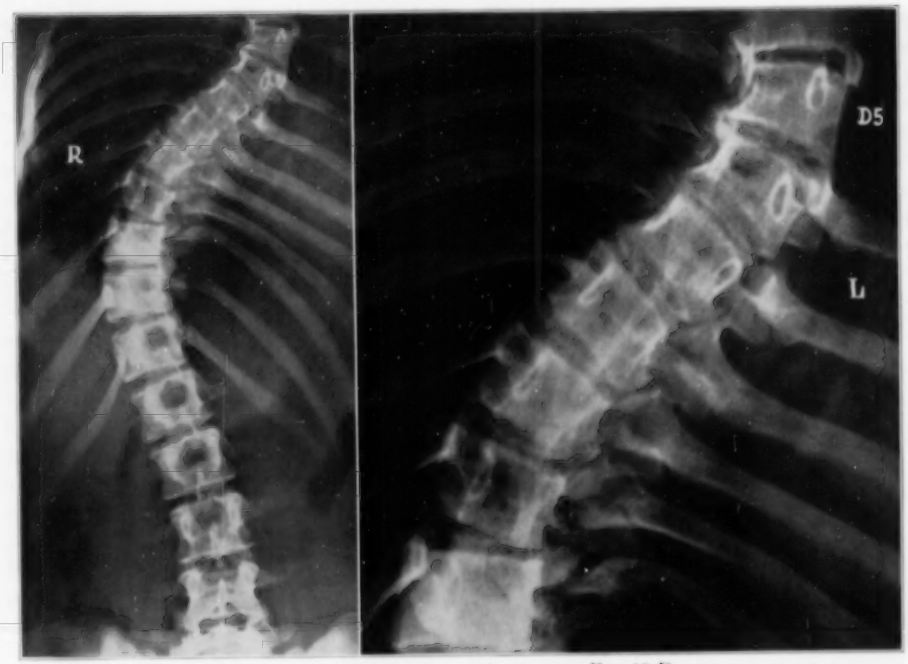

FIG. 19-C FIG. 19-D

Roentgenograms of the scoliotic curve made three years later with the patient in the supine position. The severe right thoracic curve has its peak at the ninth thoracic vertebra. Atrophy is still present.

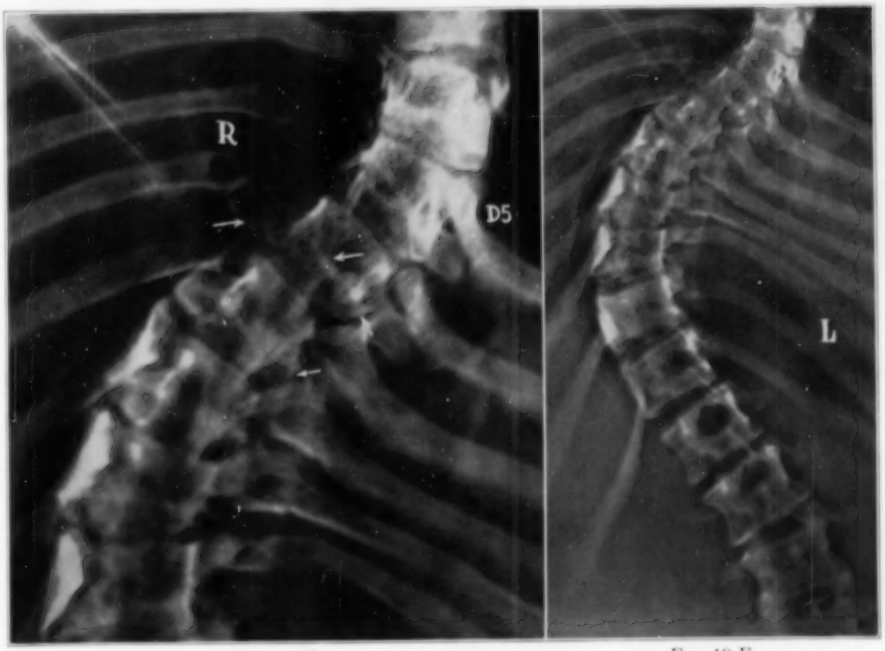

FIG. 19-E FIG. 19-F

Roentgenograms made at the same time as Figs. 19-C and 19-D with the patient in the erect position. Note the displacement of the epiphyseal ring and the apparently poorly ossified shell of the fifth and sixth thoracic vertebrae. The thoracic spine penetrates the thorax. Between the sixth and seventh thoracic vertebrae there is "step formation".

and the other is a much less dense, apparently still largely cartilaginous, portion. That this is the case can be demonstrated by the observation that *compressed vertebrae appeared to regain* normal height as seen in the roentgenograms during the movement (Figs. 19-G through 19-J). The compressed part which consists of porotic ossified tissue remains compressed, while the largely cartilaginous portion emerged and restored, in the roentgenogram, the compressed vertebra to a normal size. This movement sheds some light on the role played by the intravertebral channels. While they had often not been visible formerly, during the probable release of compression the channels opened up. It seems that in the process of compression the collapse of the "empty spaces" within the vertebral body also plays a part.

If one applies lateral traction to the concave side of the curve, such as that used in correction preceding therapeutic fusion, with the patient in prone position, postero-anterior roentgenograms reveal a significant feature of the pathological process of idiopathic scoliosis. A denser porotic part, assuming the form of the vertebra but of smaller width, moves toward the concave side, while a more translucent, almost structureless part of smaller size remains in the convex side. As previously men-

Fig. 19-G

Fig. 19-H

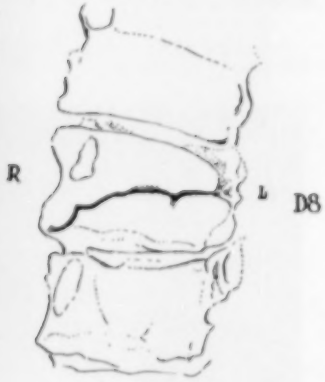

Fig. 19-I

Fig. 19-J

Fig. 19-G: Postero-anterior roentgenogram made without any bending of the trunk. There is atrophy of the spine, and at the third thoracic vertebra on the right side there is a double contour. (The roentgenogram has been reversed.)

Fig. 19-H: This postero-anterior roentgenogram was made with the girl's right shoulder rotated to the right (backward toward the convexity). Portions of the seventh and eighth thoracic vertebrae, poorly calcified and probably still cartilaginous, have emerged on the left (concave) side of the curve and seem to have restored the compressed vertebrae (Fig. 19-F) to normal size. Wide channels cross the eighth thoracic vertebra frontally and obliquely; these were not seen in Fig. 19-G. A channel, similar to those seen in the eighth thoracic vertebra, crosses the seventh thoracic vertebra frontally; this is calcified. Note double contours on the left side of the seventh, eighth, and ninth thoracic vertebrae. (The roentgenogram has been reversed.)

Fig. 20-A: Roentgenogram of the spine extending from the fifth thoracic to the ninth thoracic vertebrae in a seventeen-year-old girl. Arrows point out channels crossing the sixth, seventh, and eighth thoracic vertebrae frontally. At the lower edge of the eighth thoracic vertebra, the arrow indicates an osteophyte.

Fig. 20-B: Postero-anterior roentgenogram of the spine in a seventeen-year-old girl with left high thoracic, right thoracic, and left lumbar scoliotic curves. (Roentgenogram has been reversed.)

Fig. 20-C: Roentgenogram of the fourth to the eighth thoracic vertebrae. Large portions of the fourth and fifth thoracic vertebrae are still cartilaginous (note what appear to be large cavities in the lower portion of the vertebrae). The upper portion of the epiphyseal ring of the sixth thoracic vertebra is disrupted. There are faint shadows of channels crossing the fifth, sixth, and seventh thoracic vertebrae frontally (arrows).

Fig. 20-D: Postero-anterior roentgenogram made after lateral traction had been applied. All vertebrae from the fifth to the tenth thoracic level consist of two portions which are well defined and are separated from each other. The arrow at the lower left edge of the ninth thoracic vertebra points out an osteophyte. (The roentgenogram has been reversed.)

FIG. 20-A

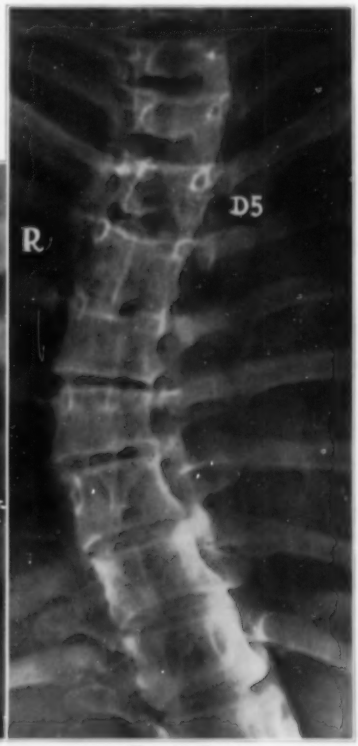

FIG. 20-B

FIG. 20-C

FIG. 20-D

FIG. 21-A

Anteroposterior roentgenograms of the spine of a fourteen-year-old girl with right thoracic and left lumbar idiopathic scoliotic curves. There is atrophy of the thoracic spine. The seventh, eighth, ninth, and tenth thoracic vertebrae consist of a dense core and a light hull (arrows).

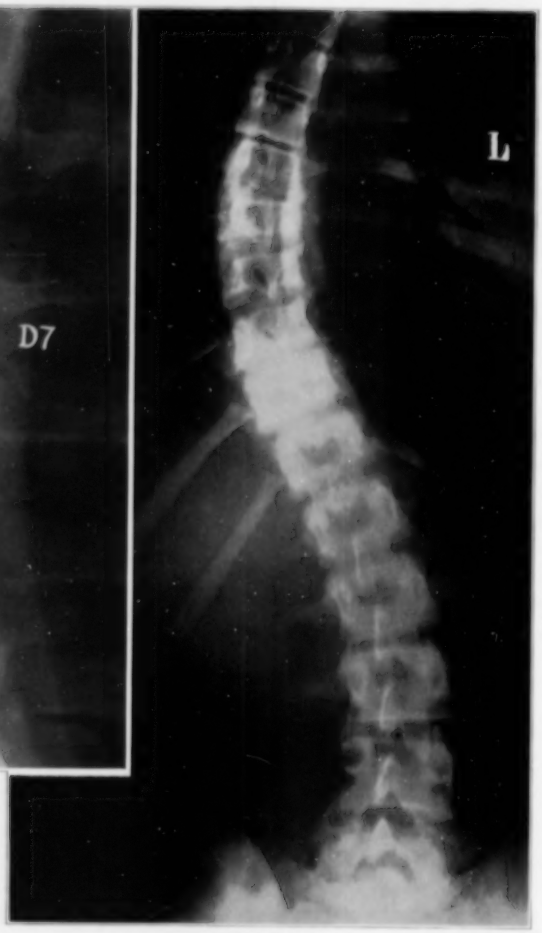

FIG. 21-B

tioned, forward rotation of the shoulder on the convex side also brought to light a vertebra consisting of two portions. One portion is a dense, compressed core, the other a less dense, non-calcified or incompletely calcified structure surrounding it or lying beside it (Fig. 20-D). The thoracic vertebrae in idiopathic scoliosis appear to consist of two portions: a dense, calcified core and a still cartilaginous or poorly ossified part. The latter may assume forms of a veritable hull (Figs. 21-A and 21-B).

The separation of the cortical shell, with the epiphyseal ring in the state of slipping, and the channels crossing or criss-crossing the vertebra may be explained in the disturbance of ossification preceded or accompanied by systemic atrophy of the thoracic spine. The distinction between the denser, calcified core and the non-calcified hull may shed light on the etiology of these processes. In the roentgenographic study of vertebrae formed of calcified and non-calcified portions, one is struck by the resemblance of their characteristics to the roentgenographic features regarded as signs of hunger osteopathy, osteomalacia, rickets, or late rickets (Figs. 21-A and 21-B). This resemblance is a matter of great significance and requires clarification.

It seems that the poorly calcified portions of the vertebrae, with or without parts of the epiphyseal ring, are extruded into the paravertebral space. There they become

compressed and assume the forms of osteophytes (Figs. 20-A, 20-B, and 20-C). In older patients, one may find large calcified portions of the epiphyseal ring extruded into the paravertebral space (Figs. 12-A, 12-B, and 20-D).

The role of the epiphyseal ring in the scoliotic process has been demonstrated in those cases in which it has either not been formed or it has been deficiently formed. The vertebral body is flattened, low, and wide; and the bone is cracked, indented, or nearly broken into two or more parts (Figs. 17-A and 17-B). The vertebral cortex is widely separated from the interior of the body, and the line of cleavage is continuous with the separating line of the deficient epiphyseal ring. In such instances, the double contour appears to be the line of separation between the vertebral cortex and the interior of the vertebra. In other instances, there is no slit, but there are two parallel vertical contours. One of these seems to be the border of the vertebra, and the other, within the vertebral body, appears to be the line separating the calcified portions from the non-calcified or poorly calcified parts (Figs. 17-A and 17-B). This is a pathognomonic sign of great value.

In the beginning, the epiphyseal ring is displaced to the side which later becomes the convexity (Figs. 18-A through 18-D). The discs, however, due to their elasticity apparently replace it, at least to a great extent. The displacement of the epiphyseal ring to the convex side represents the first step in penetration. It pulls the vertebra, sometimes the entire segment, with it. This can be seen while the process is in a florid stage by the comparison of the roentgenograms made with the patient in the supine position with those made with the patient erect. A veritable subluxation occurs with a definite "step" between the more penetrated and less penetrated portions of the spine (Figs. 19-C through 19-F).

Penetration enhances the possibility of compression, since the weight of the superincumbent body rests more heavily on the concave side. The observation that the peak of the curve is usually found at the seventh,

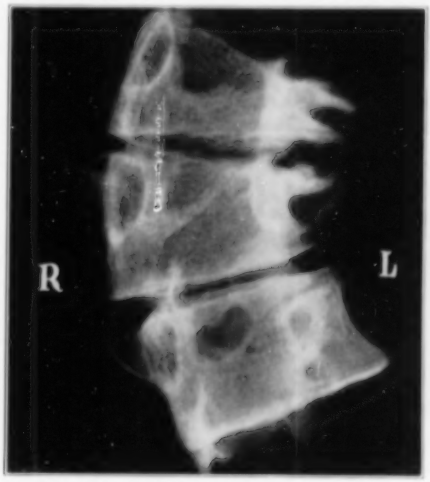

FIG. 22-A

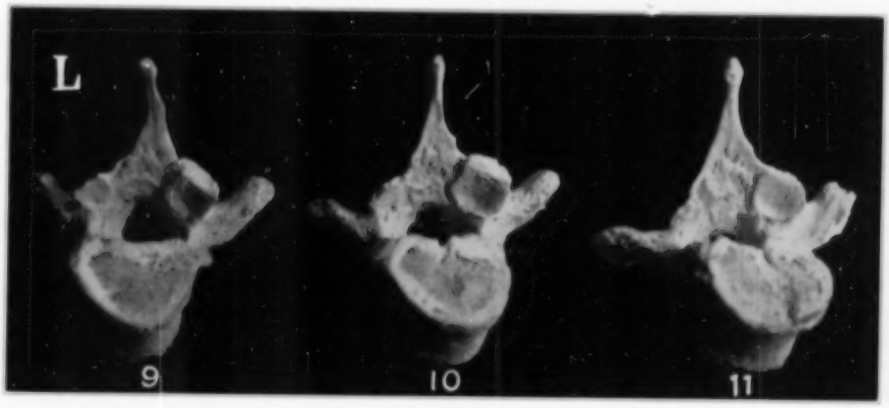

FIG. 22-B

Vertebrae from the apex (ninth to eleventh thoracic vertebrae) of an idiopathic scoliotic curve (the convex side is on the right). The articular facets are greatly enlarged on the right (convex) side and are greatly diminished on the left (concave) side.

FIG. 23

Roentgenogram of the spine of a twenty-year-old girl with paralytic scoliosis of ten years' duration. The articular facets appear to be well preserved and of about equal size on the convex and concave sides of the thoracic spine, despite the marked rotation.

eighth, or ninth thoracic vertebra shows that in that area, at the geometrical center of the spine, the greatest compression and bending stresses occur.

In the lumbar spine practically no displacement of the epiphyseal ring occurs. One of the reasons for this is that the weight of the superincumbent spine seems to play a very important role in keeping the epiphyseal ring in place. If this be the case, the separation of the epiphyseal ring ought to be most common in the high thoracic segments where weight is less and mobility is greater. The constant use of the shoulder girdle and the incessant movements of the head necessarily render the low cervical, high thoracic segments more vulnerable to disturbances in the development and fusion of the epiphyseal ring than in any other segment of the vertebral column.

Postero-anterior roentgenograms of the low cervical, high thoracic region show a serious disturbance in the ossification and development of the epiphyseal ring still going on when the deformity has already shifted from the high thoracic segment to the mid-thoracic or low thoracic levels. The low cervical, high thoracic vertebrae sometimes appear as though they had no regular epiphyseal ring at all, and large parts of the vertebral body still consist of cartilage to such an extent that they appear on the roentgenograms to have large "cavities" (Figs. 20-A, 20-B, and 20-C). The intravertebral channels still exist at an age when the rest of the deformity has reached the stage of slow progression, that is, long after growth has stopped.

The presence of a longitudinal slit between the vertebral cortex and the trabecular system within the body, occasionally observed in the lower cervical and high thoracic vertebrae, is probably also due to the relative instability of this segment (Figs. 19-G through 19-J).

The epiphyseal rings in the lumbar spine are much bulkier, thicker, and wider than are those in the thoracic spine, and they occupy a much larger segment of the vertebral surface than do those of the thoracic spine. They may also undergo earlier fusion, if for no other reason than the pressure of superincumbent weight. Yet it is not uncommon to find parts of the epiphyseal ring squeezed out of the vertebral area, especially in the first and sometimes in the second lumbar vertebrae (Figs. 25-A and 25-B).

The literature on the epiphyseal ring is scanty. In connection with scoliosis, only one reference could be found, that of Dyes in 1931. He claims that the epiphyseal ring is markedly higher and denser on the convex side and that on the concave side it might be missing.

Thus penetration and compression are characteristics of the same pathological process and are related to faulty or deficient development and fusion of the epiphyseal ring with the vertebral cortex and to osteoporosis.

During penetration and compression, the spine enters the space surrounding it by means of rotation. All this can be observed by comparing roentgenograms made with the patient in the supine and erect positions. The formation of the secondary curves takes place similarly; this will be discussed in a forthcoming study.

The pathological movement of penetration is coupled with capsular contractures. The latter, however, would be insufficient to allow such excursions as are observed in scoliosis. The examination of the scoliotic skeleton discloses that in the articulations of the thoracic spine a true *subluxation* (*later a dislocation*) takes place. The articulations on the convex side are enlarged and become deeper and wider as the deformity increases. On the concave side, the articular facets degenerate, become smaller, and lose their cartilaginous covering to such an extent that sometimes only a trace of it remains (Figs. 22-A and 22-B).

On the roentgenogram this phenomenon is hard to observe because the articular facets of the upper vertebra covering those

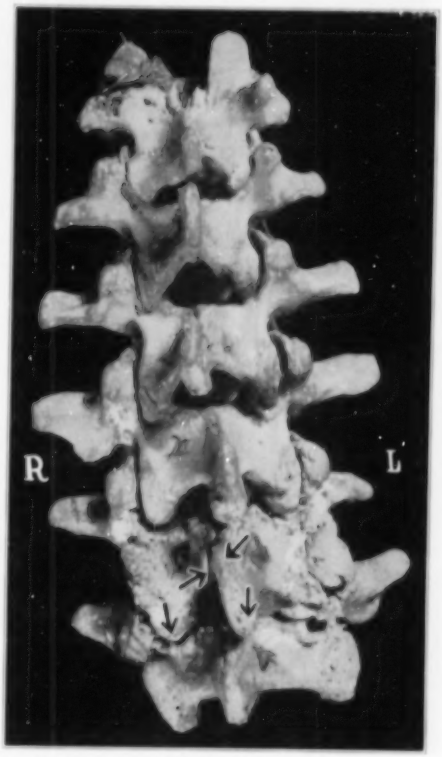

FIG. 24-A

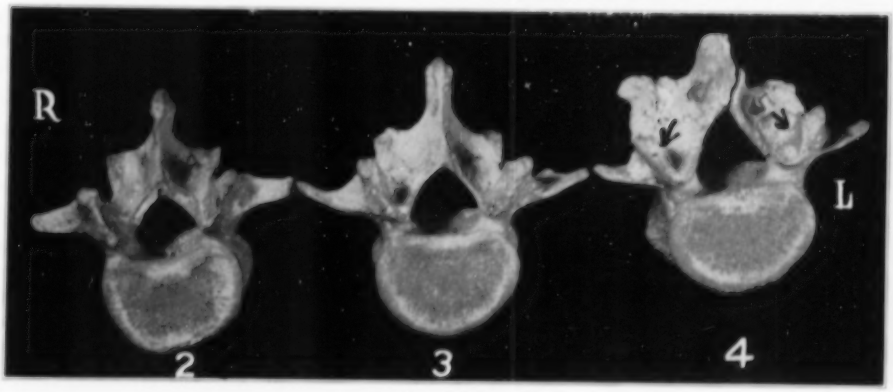

FIG. 24-B

Vertebral specimen with mild right lumbar scoliosis. There is spina bifida occulta of the fourth lumbar vertebra. Note that the upper right facet of the fourth lumbar vertebra is more oblique than the corresponding facet on the left and that the lower right articular process is short, while the corresponding process on the left is longer and is more bulky.

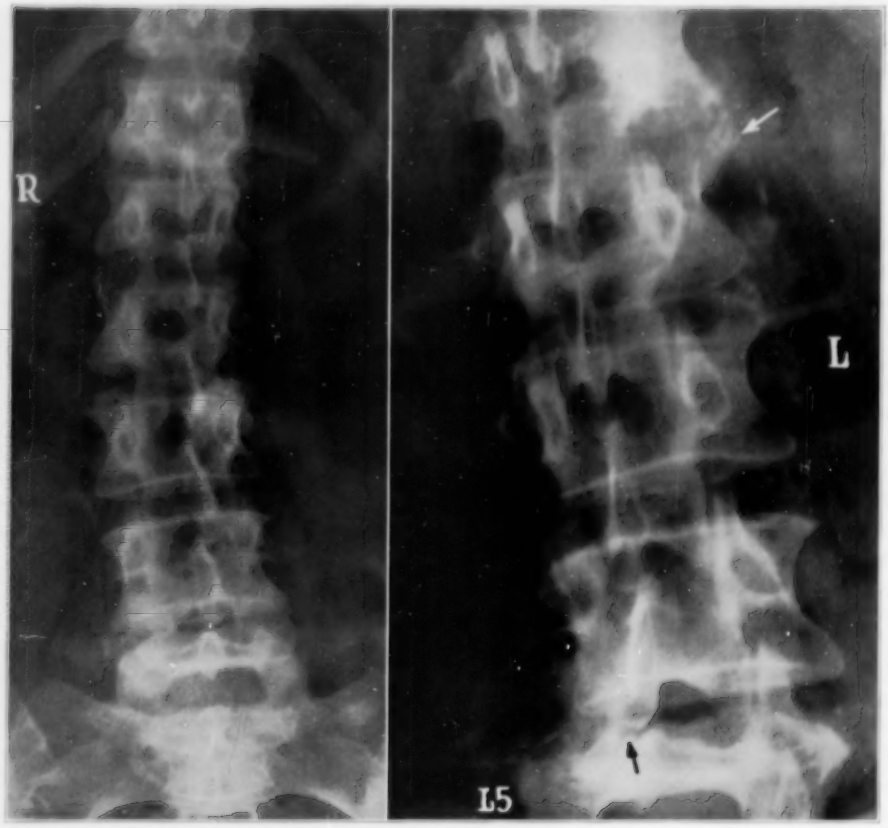

FIG. 25-A FIG. 25-B

Roentgenograms of the spine of a woman, thirty-two years old, with right lumbar scoliosis and multiple congenital anomalies. The upper right facet of the fifth lumbar vertebra is rudimentary. There is displacement of the epiphyseal ring at the left lower edge of the second lumbar vertebra. Fig. 25-B shows the spine in derotation with overcorrection of the curve.

beneath are very thin, and their bony bases are composed of highly radiotranslucent cancellous bone which gives very little shadow. On these roentgenograms in very early cases of idiopathic scoliosis of the thoracic spine the concave articular facets conspicuously diminish in height and in width, a phenomenon only partly due to the rotation of the vertebrae. This is a real diminution of the facets on the concave side due to diminished contact between the articulations and accompanied by diminished pressure. This leads to disintegration and, later, to the disappearance of the facets. The diminution of the facets is an early and ominous sign indicating that the deformity is progressing (Figs. 18-A through 18-D). The part which vertebral rotation plays in this phenomenon may be assessed by comparison of the curves of idiopathic scoliosis with the curves of paralytic scoliosis. In the latter the diminution of the facets as seen in roentgenograms is absent even when marked rotatory curves have developed over a rather prolonged period of time (Fig. 23).

The subluxation or even dislocation of the apophyseal joints is made easy by their anatomical construction.

Fick emphasizes that the intervertebral articulations of the thoracic spine possess a rather loose capsule which makes them "wobbling joints", apparently yielding to displacing forces.

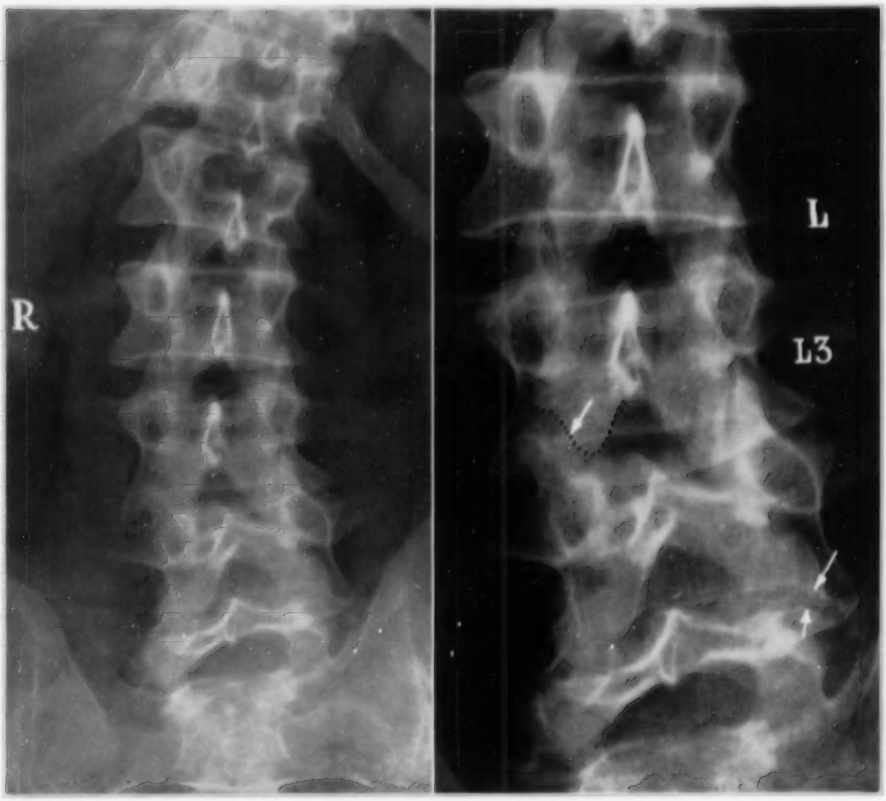

FIG. 26-A FIG. 26-B

Roentgenograms of the spine of a male, thirty-eight years old, with a right lumbar scoliotic curve and multiple congenital anomalies. The lower right facet of the third lumbar vertebra is short, broad, and malformed; the lower left facet of the fourth lumbar vertebra is missing (Fig. 26-B).

Fig. 26-B shows derotation of the spine with the scoliotic curve decreased.

THE LUMBAR TYPE OF IDIOPATHIC SCOLIOSIS

The observation stressed by the author in earlier studies that the thoracolumbar and lumbar curves are essentially rotatory curves without penetration and compression or with negligible penetration and compression [4, 5, 6, 7] brings one to an understanding that the site of the primary disturbance leading to deformity is in the neural arch. In the neural arch and the apophyseal articulations, rotation, both physiological and scoliotic, takes place.

The lumbar form of idiopathic scoliosis consists mainly in the elements of articular contracture and rotation. Both of these are accessible to correction. Hence derotation and bending of the lumbar spine to the convex side will not only correct the deformity but might also produce true, although temporary, overcorrection (Figs. 26-A and 26-B).

The observation that no separation or very little separation occurs in the components of the vertebral cortex and that compression of a great degree is encountered in the lumbar spine may be explained by the following:

1. The epiphyseal rings of the lumbar vertebrae are much thicker and much wider than those of the thoracic spine;

2. The epiphyseal rings are kept in place by the weight of the superincumbent spine and by the lumbar lordosis;

3. The interior of the lumbar vertebrae is much bulkier than that of the thoracic

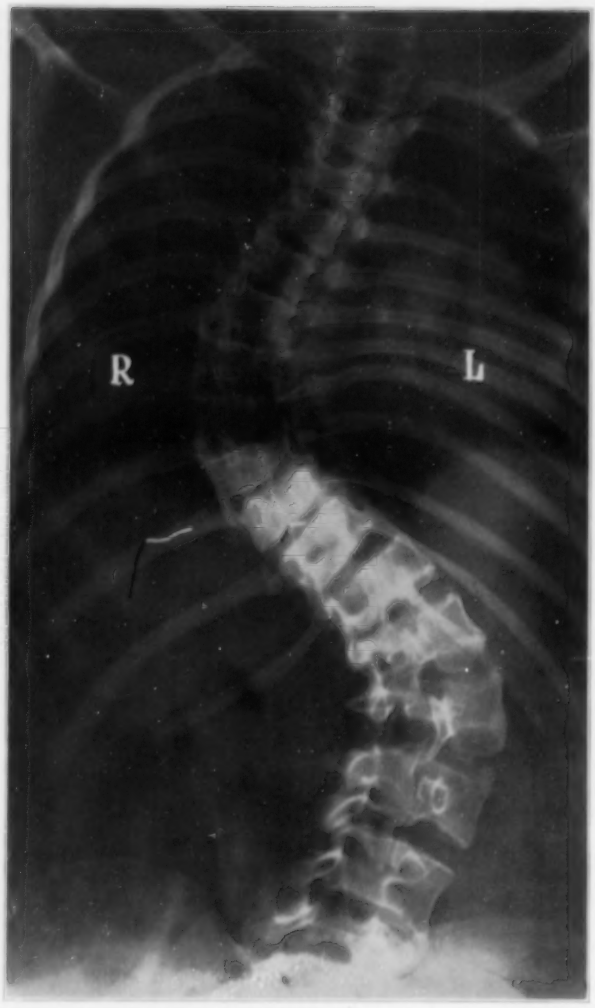

FIG. 27-A

Roentgenogram of the spine of a fourteen-year-old girl with right thoracic and left lumbar scoliosis (the combined type).

vertebrae and consists of a strong central pillar. The lateral trabeculae which are a thick network may bring about an earlier and firmer fusion between the epiphyseal ring and the vertebral body. This is especially true since they are subjected to much greater pressure.

In the lumbar spine, the degree of rotation depends, roughly speaking, on the width of the space between the articular facets facing each other. If the space is wider than the normal, the gap between the facets becomes wider too, so that rotation may increase. As previously mentioned, this gap is widened by lumbar kyphosis and by changed divergence (obliquity) of one or both facets.

Increased obliquity of the inferior facets is frequently encountered in spina bifida occulta and is such that the gap between the spinous processes forms a weak spot in the neural arch. Physiological movements of the lumbar spine bend the facets on one side because the neural arch does not consist of one piece, but of two. The slit produced by the non-union of the spinous processes may become wider, causing the articular facets to become more or less oblique. Thus, the gap between the corresponding facets widens on one side and narrows on the other (Figs. 24-A and 24-B). More serious in its consequences are the cases in which there is a true laminar defect. In these, the neural arch is divided into two parts. The facets are either rudimentary or are not to be seen. Sometimes no articular processes, or faulty articular processes, are observed.

Another cause for the incomplete attachment of facet to facet is the insufficient length of the superior facet. The latter may not cover the entire surface of the inferior facet, since it may be too short to do so. In other instances, the *upper facet does not reach the lower facet* because it is either too short or is deformed (Figs. 25-A, 26-A, 26-B, and 27-C).

The most severe cases are those in which the inferior facet is malformed or is insufficiently developed, and the inferior facet, instead of embracing the superior facet from the

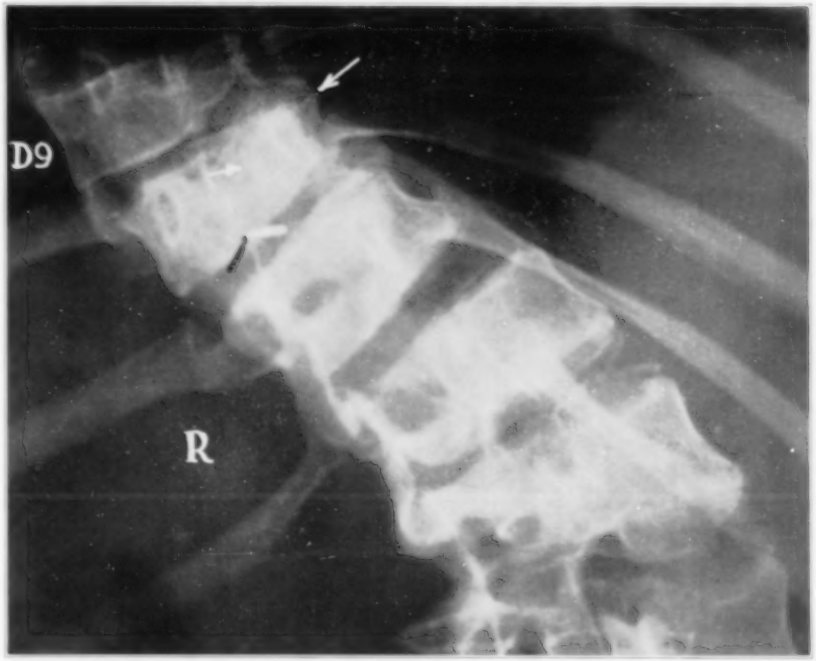

FIG. 27-B

Fig. 27-B: Lower segments of the thoracic spine. The vertebrae are flat. To the left side of the ninth and tenth thoracic vertebrae double contour is apparent. Between the ninth and tenth thoracic vertebrae the epiphyseal ring (rudimentary and broken in several places) has been displaced into the left side (arrow). The tenth thoracic vertebra is crossed by infraction lines (arrow).

Fig. 27-C: Roentgenogram of the lumbar spine. The left upper facet of the third lumbar vertebra ascends medially to the deformed lower facet of the second lumbar vertebra which descends laterally. The rudimentary lower facet of the fourth lumbar vertebra is situated laterally.

FIG. 27-C

lateral side, ascends medially to it. In some instances, the superior facet may be not present at all or may be only a rudimentary structure (Fig. 27-C).

In the lumbar type of idiopathic scoliosis, the disturbance leading to the deformity is in the neural arch—the functional segment of the vertebra.

In all instances of this type of idiopathic scoliosis, derotation of the lumbar spine either straightens the lumbar curve completely or decreases it considerably. Thus, *the rotatory factor is shown to be the main element in the deformity.* Increased pathological rotation is, therefore, made possible by definite anomalies in the neural arch; this proves that the *lumbar type of idiopathic scoliosis is essentially of congenital origin.*

Another argument in favor of the congenital nature of the lumbar type of idiopathic scoliosis is that the incidence of left convex curves and of right convex curves, at least in the material of the author, is about the same. This is in accordance with the observed incidence in other congenital anomalies of the skeleton without predominance on either side. The partially asymmetrical gait causes the predominance of right convex thoracic curves since the pathological anatomical process concerns the entire vertebra. The congenital anomalies in the neural arch of the vertebrae appear to be dominant over the impact of gait. For the impact of gait to dominate in the process would require the predominance of left convex curves, as is seen in physiological scoliosis.

Derotation is easily carried out by rotating the pelvis in the direction of the deviation of the spinous processes, that is, toward the concavity of the curve. It is done simply by elevating the side of the pelvis on the convex side with a pillow (Figs. 25-A and 25-B). Derotation enables us to see the extent of the congenital anomaly and to discern its nature.

With advancing years, mild signs of compression may be seen with parts of the epiphyseal ring extruded into the concavity of the curve, especially at the first lumbar vertebra and rarely at the second lumbar vertebra (Figs. 25-A and 25-B). The emergence of the compression may be caused by:

1. The long time elapsed after the establishment of the deformity with greater weight resting on the concave side of the vertebra;

2. The gradual decrease in the elasticity of the discs—a physiological accompaniment of the process of aging which exposes the vertebrae to increasing pressure;

3. Osteoporosis of the spine beginning with advancing age.

Two elements of this type of scoliosis deserve consideration. The first is the frequent subluxation of the symphysis. Whether this is secondary to the deformity or a primary, congenital sign, findings in early cases of scoliosis shall decide.

The second element is the shortening of the lower extremity on the side of the convexity of the curve. This element has been found in such a large number of cases that the author presumes that it is one of the congenital anomalies encountered in this form of scoliosis. Since shortening of one extremity (as in congenital dislocation of the hip) is regularly *not* followed by scoliosis, its etiological significance with regard to scoliosis lies apparently in its association with other congenital anomalies in the lumbar spine.

In general, the thoracolumbar and lumbar curves are prognostically more favorable. An important characteristic of the curves is that *all of the vertebrae forming the curve are rotated in the same direction.* The frequently mild secondary curves may show little or no rotation. If they show rotation, the direction of rotation is identical with that of the primary curve. This will be discussed in forthcoming studies.

It is worth mentioning that in the "juvenile" form of the low-back syndrome, which frequently starts in the late twenties, the lumbar type of idiopathic scoliosis is encountered in the majority of patients. In the concept of this author, the rotation of the vertebrae narrows the intervertebral foramina, affects the neurovascular structures which emerge there, and may eventually lead to the congestion of the intraspinal venous system and sciatica [11, 12].

COMBINED THORACIC AND LUMBAR CURVES

It is not infrequent to encounter severe forms of scoliosis in which a great number of congenital anomalies occurring in the lumbar spine are coupled with signs encountered in idiopathic scoliosis of the thoracic spine (osteoporosis, deficient formation of the epiphyseal ring, the separation and displacement of the epiphyseal ring, large or small channels within the vertebral body, failure of fusion between the cortex and the trabecular system manifested in double contours, fissures, cracks, and signs of non-ossified or poorly ossified structures within the confines of ossified portions of the vertebral body) (Figs. 27-A, 27-B, and 27-C).

As previously mentioned, this form is prognostically the most serious, since it involves the entire spinal column.

THE PROGRESSION OF IDIOPATHIC SCOLIOSIS

It has to be assumed that all forms of idiopathic scoliosis start at a very early age. It is not possible to say when idiopathic scoliosis begins until the infantile form of scoliosis has been carefully analyzed.

There are a number of important factors to be mentioned. It frequently occurs that a real idiopathic scoliosis in the upper thoracic segment develops but stops at a mild stage. This has been observed mostly in males.

Another feature of significance is that idiopathic scoliosis does not develop gradually, getting worse and worse as the years pass. Frequently, after its first establishment in the upper thoracic segment, the entire process seems to have stopped. A few years after the scoliosis has been diagnosed everything seems to have returned to normal except for the upper dorsal curve which had not materially changed. There are at that time hardly any signs of further involvement of the middle or lower segments; only a generalized atrophy and signs of mild compression are present. Then at the age of ten to twelve years a fully developed and uncontrollable idiopathic scoliosis is present (Figs. 18-A through 19-F).

The age of the first stretching (up to the age of four) and that of prepuberty bring idiopathic scoliosis into full swing, thus demonstrating the connection of idiopathic scoliosis with the physiological process of growth and ossification.

Whether the lumbar type belongs to the well defined entity of idiopathic scoliosis is questionable. The fact that the lumbar type is definitely of a congenital nature would exclude it. However, the decision has to be deferred until the possibility of congenital manifestations in the thoracic type has been clarified, since the combined thoracolumbar type is unquestionably congenital in character.

In the present paper it has not been possible to discuss all of the questions and problems relating to idiopathic scoliosis. Among the problems, a discussion of which has been deferred, are secondary curves, convex rotation, and the relationship between deformity and posture. Also deferred is a discussion of therapy; this has been reserved for a forthcoming study.

COMMENT

1. The presence of vertebral channels in the form encountered in idiopathic scoliosis is probably part of a pathological process characterized by atrophy.

2. Since atrophy may be the remote cause of the separation of the epiphyseal ring, it thus may be the primary pathological process in scoliosis.

3. The separation and displacement of the epiphyseal ring, the outstanding feature in the development of deformity, may be analogous with a slipped epiphysis at another site. The slipped epiphysis, either in the femoral head or in multiple slipping, is usually preceded or accompanied by definite atrophy of the structures around the area of separation.

4. Generalized atrophy and the separation of the vertebral cortex from the intra-

vertebral trabecular system deprive the vertebra of the most efficient factor in counteracting compression.

5. Since growth of the vertebra takes place within the body bordered by the vertebral cortex, it necessarily follows that the compression of the structures serving growth is accompanied by the disturbance of growth. Thus, the retarded growth of a vertebra is a secondary trait of idiopathic scoliosis and not the primary factor as claimed by Port and others.

6. Slipping of the epiphyseal ring in the lumbar spine is nearly always a late phenomenon. However, this is not always the case, especially when serious disturbances in the development of the laminae are present. In such cases the slipping may already have taken place in the second decade of life.

7. Congenital anomalies are not restricted to the lumbar spine. Careful search may disclose them also in the thoracic and even in the cervical region.

8. The question may justifiably be raised of whether or not the pathological process described in this study is not secondary to the development of scoliosis. In the thoracic spine the characteristics of the pathological process have often been found in the vertebrae several years prior to the development of the main curve. An even more cogent reason for the assumption of this author is offered by the forms of scoliosis definitely other than idiopathic in their orgin. Paralytic scoliosis, post-thoracoplastic scoliosis, and congenital scoliosis show hardly any of the signs described in this study which are attributed to the main pathological process of idiopathic scoliosis, despite their long standing.

In the lumbar spine the changed obliquity of the lateral facets might be attributed to the deformity. Naturally the obliquity changes with the increase of rotation. However, if rotation were the primary factor modifying the obliquity, the latter necessarily would be found in all vertebrae concerned. This is definitely not the case. Moreover, the presence of the obliquity in one or two facets is hardly ever the only congenital abnormality. Finally the observation that the incidence of right convex and left convex curves is roughly the same leaves little doubt of the congenital nature of the deformity.

SUMMARY

1. Scoliosis has four fundamental characteristic features as seen in the roentgenograms: Penetration or a transverse shift of the spine into the space surrounding it, contracture of the spine, rotation of the vertebrae, and compression of the vertebrae on the concave side of the curve.

2. Penetration and compression are the essential scoliotic signs and are not encountered under physiological conditions.

3. The prevention of penetration is physiologically carried out by a passive mechanism.

4. The universal mechanical factor of all forms of acquired scoliosis is human gait, which in the presence of a definite pathological process brings about the deformity.

5. Rotation of the shoulders and of the trunk, or of the pelvis, is accompanied by rotation of the spine in the opposite direction.

6. The compression on the concave side is a primary characteristic of idiopathic scoliosis in the thoracic spine.

7. The vertebra is protected against undue compression by the disc, by the cartilaginous plate, and by the vertebral cortex which is composed of the end plates covering the upper and lower surfaces, of the circular bony hull, and of the epiphyseal ring.

8. The separation of the vertebral cortex from the intravertebral system, notably the separation of the epiphyseal ring and its partial displacement, represents the basic pathological process of idiopathic scoliosis in the thoracic spine. Separation is preceded by the infantile (juvenile) form of osteoporosis of the spine.

9. Postero-anterior roentgenograms reveal the presence of channels crossing the vertebrae in a frontal direction.

10. The compressed vertebrae, as seen in the early stages, consist of two distinct portions: One is an ossified and porotic part, the core; the other, surrounding it or lying beside it, is a poorly or non-calcified, still more or less cartilaginous, portion.

11. In a typical case, idiopathic scoliosis of the thoracic spine starts in the cervicothoracic segment, and several years may pass before the middle and lower thoracic regions become involved. The process in the uppermost region presumably begins in the first four years of life.

12. Penetration and lateral movements, to the extent observed in scoliosis, are caused partly by subluxation in the articulations between the vertebrae.

13. Since idiopathic scoliosis of the lumbar spine is essentially of a rotatory nature without compression, a distinction is made between idiopathic scoliosis of the thoracic and lumbar spine.

14. Idiopathic scoliosis of the lumbar spine is made possible by congenital anomalies in the articular system of this region. The disappearance or decrease of the lumbar lordosis materially contributes to the development of the deformity.

15. Extrusion of the epiphyseal ring, if it occurs at all, is mostly a late phenomenon in the lumbar region.

16. The lumbar type of idiopathic scoliosis is characterized by rotation in the same direction of all vertebrae involved. The lumbar type is prognostically more favorable than the type involving the thoracic spine.

17. The prognostically most serious cases are those in which the congenital anomalies in the lumbar segment are combined with the pathological process encountered in the thoracic type of the deformity.

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DISCUSSION

Epiphyseodesis

(*Continued from page 555*)

insert a nail accurately from the trochanteric region, whereas I can place pegs accurately because the neck and most of the head can be clearly seen and only a short distance must be traversed.

Dr. J. Albert Key, St. Louis, Missouri: I would like to ask two questions. The first is how to decide whether or not to perform this operation if the roentgenographic findings are normal. I have seen many older children and adolescents with hip symptoms whose symptoms subsided without operation. I feel that, if we are going to stop the growth of an epiphysis and subject the patient to such an extensive procedure, we ought to be sure that we are dealing with a slipped epiphysis and not with an ordinary synovitis or another condition which will get well without surgery.

The other question is: Has anyone considered the question of shortening? There are people who believe that there is no growth at the capital epiphysis of the femur, but, if that were true, it would indeed be an unusual epiphysis. The hazard of shortening must therefore be kept in mind. I have seen short necks after epiphyseal fusion.

Dr. Heyman (closing): I agree with Dr. McCarroll that one should generally be conservative. I have not been satisfied, however, with my own results after nailing slipped epiphyses, and I have observed many patients of others in whom the results have not been good after nailing. Accordingly, I have sought a better method of treatment. One might call these clinical experiments.

Dr. Howorth has had more experience with the operation of epiphyseodesis. My results may be considered as a confirmation of his conclusions.

Dr. Key's remarks are well in order. There are many instances, as we all know, when the diagnosis of the very early case of slipping is difficult. We do not recommend this operation as an emergency procedure without at least a short period of observation under protective care of the hip. When the diagnosis is unquestionable, however, we believe it is best not to delay epiphyseodesis, for the hazard of complications is less in this method than in conservative treatment. Fusing the upper femoral epiphysis in this age group does not cause any important disturbance in growth. The maximum shortening has been one-half inch, which is not of any clinical significance.

TRAUMATIC SUBLUXATION OF THE RADIAL HEAD IN YOUNG CHILDREN

BY JAMES T. GREEN, M.D., AND FRANCIS H. GAY, M.D., COLUMBIA, SOUTH CAROLINA

A screaming young child with a dangling arm requires immediate attention. Seven such cases within six months created sufficient interest to prompt the authors to review the literature on traumatic subluxation of the radial head in children. Van Arsdale in a very lengthy treatise gives credit to Hippocrates for an early description. He also credits Fournier for first accurately describing the injury (1671). He refers to many authors who wrote on the subject in the eighteenth and nineteenth centuries, many of whom were either German or French. Since Van Arsdale's paper, there have been relatively few articles and none could be found recorded in *The Journal of Bone and Joint Surgery*. Many of the commonly used textbooks make no reference to it. A few describe it adequately[5,7]. Boyette states that this injury is a pediatric problem and that "By referral and conversation it has been learned that orthopedists generally are not familiar with subluxation of the head of the radius . . .". Costigan urges that a more prominent place be given to this entity in orthopaedic and traumatic texts. A few additional articles[1,4,6] were found in which cases were reported.

This joint injury is apparently a rather frequent one, and a description of it should be available to all orthopaedic surgeons. The purpose of this paper is to recall the entity and to present the typical clinical picture as observed in seven cases. Nothing original is claimed in this presentation.

All of the patients were referred by physicians who had seen the children. In two, the diagnosis of brachial plexus injury had been made. All of the children in this series were between one and three years of age. Six were seen within two hours of the injury. One was seen the next day. One child was seen for two separate episodes.

The history in each case was essentially the same. A sudden pull had been exerted on the child's extended arm in an attempt to keep him from falling. Immediately following the injury, the child began to scream, refused to use the arm, kept it dangling at the side, and resisted any attempts to move the extremity. In all cases, the parent or the nurse who was responsible for the injury was extremely apprehensive that she had caused some irreparable damage. When the child was first seen, the involved arm appeared flail. The child consistently refused to use the arm, and the forearm was held in pronation. Gentle attempts to examine the elbow caused the child to pull away. It was difficult to demonstrate a point of maximum tenderness; in two cases, there appeared to be elbow tenderness. Finger motion could be demonstrated in four of the children, a lollypop being used as a lure. There was no swelling or discoloration. All motions of the shoulder, elbow, and wrist were resisted. Color, temperature, and pulse were normal.

Roentgenograms of the arm revealed no abnormality in the bones or joints. The development of the arm appeared normal in all, and the center of ossification for the head of the radius had not appeared.

Treatment in all cases consisted in gentle flexion of the elbow to 90 degrees, application of mild pressure over the radial head with the thumb, and gentle rotation of the forearm. As the forearm was supinated, a click could be felt in the region of the radial head. Gentle manipulation was all that was necessary in six of the seven cases. The seventh child required fairly firm manipulation. No anaesthesia was required. As soon as the elbow "click" was palpated, there was a spectacular change from a crying child to a peaceful child who was willing to use the arm almost immediately in a normal manner. No type of immobilization was used after the first incidence of subluxation.

(*Continued on page 662*)

TRANSPOSITION OF THE BICEPS BRACHII FOR TRICEPS WEAKNESS

BY Z. B. FRIEDENBERG, M.D., PHILADELPHIA, PENNSYLVANIA

From the Department of Orthopaedic Surgery,
University of Pennsylvania Hospital, Philadelphia

The surgical treatment of disability of the elbow due to muscle weakness resulting from poliomyelitis or other flaccid paralysis has usually been concerned with the restoration of flexion, since gravity extends the elbow and paralysis of the triceps seldom causes significant disability. However, if there is marked weakness of both the lower extremities and the trunk, sufficient muscle power to lock the elbows in extension while the patient is crutch-walking, arising from a bed or chair, or reaching for objects overhead is an important asset.

Ober and Barr [1] reported a series of patients handicapped by triceps weakness who were treated by transposition of the brachioradialis muscle by rerouting of this muscle at the elbow to a more posterior position. In each case the extensor power was increased so that the patient could maintain extension of the forearm against gravity.

The patient reported here was severely handicapped by paralysis of his lower limbs and trunk. Although he had normal flexion of the elbows and could lock his elbows if he supported himself on a chair or on his crutches with his hands, his elbows would buckle when he attempted to rise from a chair and to support himself with his crutches. It was believed that this patient needed greater power of extension than could be obtained by transplantation of the brachioradialis. Accordingly, transplantation of the biceps was undertaken.

V. H., a male twenty-one years of age, was first seen in April 1951. He had had a severe attack of poliomyelitis eight months before. Both lower limbs were flail, and there was weakness of both the abdominal and the spinal muscles. The upper extremities were normal with the exception of both triceps muscles, which were rated as poor.

The patient was fitted with long braces and a spinal support, but made poor progress in crutch-walking since, because of weakness of the triceps, he was unable to bear weight on his hands in advancing his crutches. Pain and numbness in the upper extremities from pressure of the crutches in the axillae quickly followed any attempt to walk more than a few steps. Furthermore, the patient was unable to rise from his chair or to sit down without assistance because of his poor elbow stability.

In October 1952, the right biceps was approached through a straight incision, paralleling its lateral border and extending from ten centimeters above to five centimeters below the elbow. The musculocutaneous nerve was identified at the point where it becomes subcutaneous, emerging between the biceps and brachialis muscles. It was mobilized from the undersurface of the biceps for a distance of about five centimeters. Further isolation was not attempted because of possible injury to motor branches of the brachialis and biceps muscles. The biceps tendon was dissected free from the lacertus fibrosus and divided close to its attachment to the radius. The muscle was then mobilized to a point ten centimeters proximal to the elbow joint. The radial nerve was identified and protected from injury before the brachioradialis was retracted laterally.

A second incision was then made over the olecranon process and the biceps tendon and distal muscle belly were passed subcutaneously across the lateral border of the arm into this incision. The tendon was found to be too short to reach the olecranon. A flap of triceps aponeurosis which remained attached distally, 2.5 centimeters long, was fashioned and the biceps tendon was sutured to the flap. The arm was immobilized in full extension for four weeks, after which motion and muscle training were begun. An additional month was required for the transplant to gain function and for a full range of elbow flexion to be regained. Six weeks after operation the patient was able to extend the forearm against gravity plus seven pounds of resistance. His ability to handle a crutch and arise from a chair with the aid of this arm was so much improved that he requested that the same procedure be done on his left side.

The second procedure was done in June 1953 and differed from the initial procedure only in that a Z-shaped incision was made, the middle arm of the Z following the flexion crease of the elbow to avoid the development of a long straight scar over the anterior aspect of the elbow.

One year after the first and five months after the second operation he had a full range of elbow motion.

In spite of the biceps transplants, he could flex the elbows against a resistance of fifteen pounds bilaterally. To determine how much weight was needed to overcome the extension power of the transposed biceps, the patient was placed prone upon an examining table, his arms fully extended, so that they projected outward from the sides of the table. With each shoulder rotated in order to keep the olecranon process superiorly, weights were added to a handle grasped in each hand. On the left, eight and one-half pounds and on the right seven and one-half pounds could be supported without flexion occurring in the elbow. The ability to extend and lock his elbows without awkward shifting of body weight had helped the patient to become independent, allowing him to move from bed to wheel chair to crutches without assistance. Before operation crutch-walking had induced paraesthesia in the upper extremities because of the disproportionate amount of weight borne in the axillae. This has been fully relieved and the patient's ability to walk on crutches has increased.

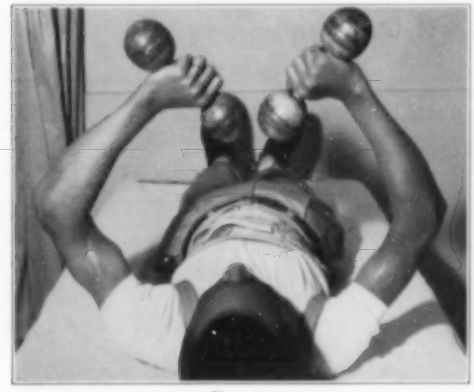

FIG. 1

FIG. 2

Fig. 1: After transposition of the biceps, weights of five pounds can be supported against gravity with the elbows flexed. The patient is able to extend the elbows against a force of over eight pounds on the left and seven pounds on the right.

Fig. 2: The transposed biceps may be seen to stand out on the right when the patient assumes a sitting position. Prior to transposition of the biceps muscle he had not been able to support himself in this position.

This procedure would appear to be of great value in the severely paralyzed patient who has flexor power of the elbow but lacks sufficient triceps power to lock the elbows in extension for crutch-walking and for getting in and out of bed or a wheel chair.

Dr. Leo Mayer in a communication to the author has described a similar surgical procedure which is included in this report.

E. L., a sixteen-year-old male, suffered a fracture-dislocation of the third and fourth cervical vertebrae as the result of a diving accident in 1949. When he entered the Hospital for Joint Diseases in March 1951, there was complete paralysis of the upper extremities. Both elbows were held flexed at an angle of 50 degrees, because of the contracture of the biceps and brachialis anterior. Both tricipites were completely paralyzed. Because of this peculiar condition, crutch-walking was impossible. It was therefore decided that a transplantation of the biceps was indicated. The operative notes were as follows:

A fifteen-centimeter incision was made over the anterior aspect of the elbow with a small horizontal arm at the crease of the elbow, so that the incision formed a long Z. The biceps tendon was exposed and found to divide into a medial portion terminating in the lacertus fibrosus and a lateral portion which inserted into the radius. These portions of the tendon were divided as far distally as possible. They were stitched together by means of a few chromic sutures. The brachialis anterior was then exposed and was divided at its insertion into the coronoid process. Division of the biceps permitted extension of the arm to about 140 degrees. After division of the brachialis anterior, it could be extended to 155 degrees. The anterior wound was closed.

A second incision, 7.5 centimeters long, was made on the posterior aspect of the arm, exposing the triceps. A superficial tunnel was formed which passed through the subcutaneous tissues and led from the anterior to the posterior wound. Through this tunnel the biceps tendon was drawn. It was then passed obliquely through a slit in the triceps tendon and fastened with three fine-wire sutures. The terminal portion was drawn through

a second slit. During this procedure the triceps was held taut and the arm was kept in maximum extension. The wounds were closed and a plaster-of-Paris splint was applied with the arm in extension of 150 degrees.

The left arm was operated upon on April 2, 1951, and the right on May 7, 1951. The same procedure was carried out on both sides.

The clinical result was gratifying. The patient was able to extend both arms to about 150 degrees. Unfortunately, however, the main purpose of the operation—to rehabilitate him sufficiently for crutch-walking—was not attained. This was due to the extensive paralysis of the trunk muscles and the marked weakness of the other muscles of the upper extremity. From other points of view, however, the operative result was of the greatest value to the patient, since it enabled him to hold a book in a comfortable position, turn the pages, and, after several months, to begin to learn typewriting. When he was seen a year later, his mood had changed from one of despair to one of optimism. He was studying for his examinations, had learned to typewrite fairly well, could eat by himself, and could even attend to his toilet needs.

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A UNIVERSAL-JOINT CLUB-FOOT SPLINT

BY ALEXANDER GIBSON, M.D., WINNIPEG, MANITOBA, CANADA

The use of a splint instead of plaster in the treatment of club-foot has many advantages. Since their introduction by Denis Browne some twenty years ago, splints of various patterns have been devised. In all of them, the plane of the foot piece remains fixed in relation to the adjoining part of the bar. When varus is pronounced, some force may be necessary before the infant's foot can be secured to the foot piece by adhesive. In the normal foot, the combination of ankle joint with subtalar joints provides the equivalent of a ball-and-socket joint of limited range.

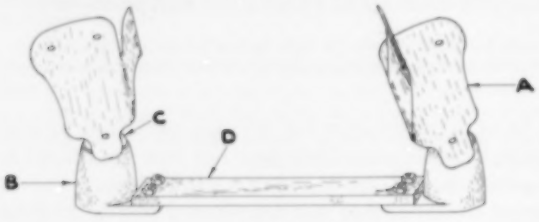

Fig. 1-A

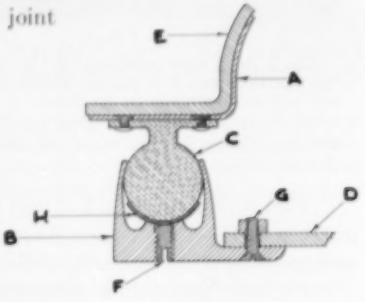

Fig. 1-B

A: Foot plates.
B: Socket frame.
C: Ball assembly.
D: Spacer bar.
E: Sponge-rubber padding.
F: Allen screw.
G: Bolt and nut to hold spacer bar.
H: Concave steel disc to protect ball.

The universal-joint splint to be described represents the application of this ball-and-socket principle in the splint itself. It gives much increased flexibility both in applying the splint and in controlling the position of the foot. The idea was suggested by the appliance used in photographic work to attach a camera to a tripod head in such a way as to give the necessary controlled flexibility. A number of modifications have been tried during the last five years. The latest is shown in Figures 1-A and 1-B.

The foot plates, made from 3SH aluminum sheet, 0.045 inch thick, are 1⅜ to 1⅞ inches wide and 4¼ inches long. The vertical section is 1½ inches wide and 1¼ inches high. The socket frame, made from cast aluminum, has an outside size of 1¼ inches high, 1¼ inches wide, and 2¼ inches long. The ball assembly is turned from 24ST alu-

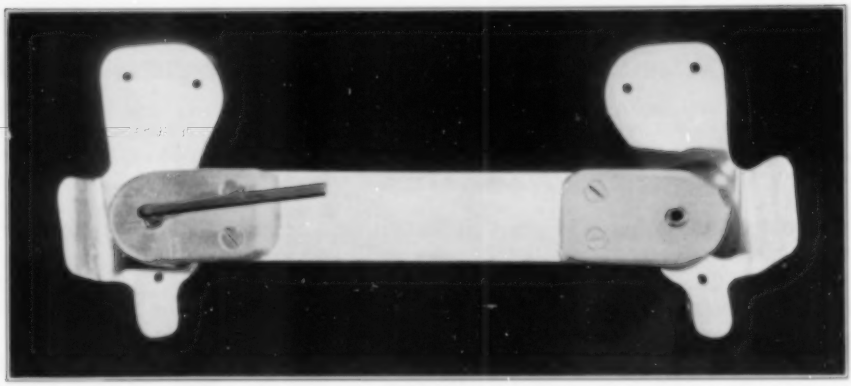

FIG. 2

Brace seen from below, showing simplicity of adjustment with Allen wrench.

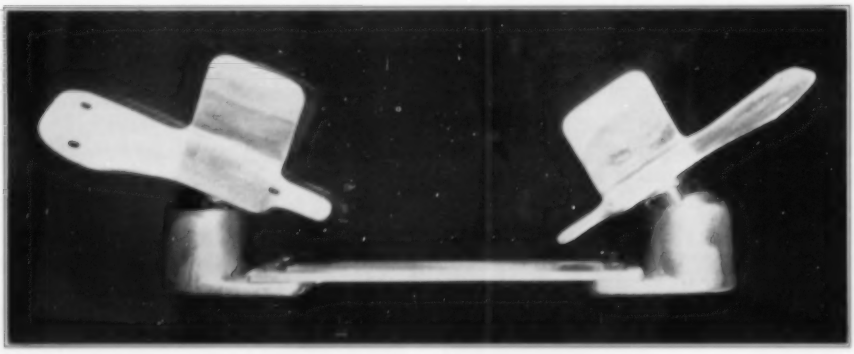

FIG. 3

Showing position of foot plates in eversion.

minum alloy, and measures 1⅜ inches high. The ball is one inch in diameter. There are three spacer bars, made from 24ST aluminum alloy, ⅛ inch thick, 1¼ inches wide, and 5½ inches, 7½ inches, and 9½ inches long; these lengths are such that the distance *C* to *C* may be 7 inches, 9 inches, or 11 inches, respectively. Sponge rubber about 3/16 inch thick is attached with rubber cement to the foot plates. Later, the rubber is removed, and the shoes are fastened to the plates by bolts through the holes provided. The Allen screws measure 5/16 inch by ½ inch, and with them a hexagonal key is used. Cadmium-plating of the bolts, nuts, and Allen screws protects them against corrosion. The brace itself, being made of aluminum, will not rust.

Changing the position of each foot on the splint is very simply carried out: By a slight reverse turn, the grip of the Allen screw on the ball-bearing is loosened, the foot plate is adjusted to the new position, and the screw is tightened again. Eversion of the heel, in particular, seems to be under better control.

The apparatus has been well tested, and has proved efficient. The technical experimentation was done for me by Mr. R. Fairbairn of Winnipeg. He has supplied the drawing and the specifications.

PELVIC PLATFORM BRACE FOR SUBLUXATION AT THE SHOULDER

BY ROBERT V. MILLER, JR., M.D., AND KARL H. HAASE, M.D., LOS ANGELES, CALIFORNIA

From the Physical Medicine and Rehabilitation Service, General Medical and Surgical Hospital, Veterans Administration Center, Los Angeles

Shoulder subluxation, a frequent clinical problem, is encountered when paralysis or atrophy of muscle occurs about the shoulder girdle and arm as a result of disease or injury. Poliomyelitis has been the most frequent cause in our series. Surgical correction of the paralytic shoulder has been notoriously unsuccessful where there have been several severely paralyzed muscles about the shoulder joint.

Harmon noted, in speaking of surgical reconstruction of the paralytic shoulder, that the greater the number of muscles involved, the more profound the ataxia and the less likely it is that the condition would be remedied by muscle transplantation. In evaluating the results of trapezius transplants, Haas had previously noted poor results when the paralysis about the shoulder was extensive.

In marked weakness or atrophy of the shoulder-girdle musculature, the glenohumeral joint may become subluxated as weakened muscles, tendons, and joint capsule are stretched by the weight of the upper extremity. Cotton observed that it was "common but apparently unwritten, — the subluxation downward in cases of injury not from a single trauma, but from the weight of the arm made possible through gradual exhaustion of the muscles—primarily of the deltoid muscle."

The usual method of treatment is to apply a sling to the affected arm with a strap over the opposite shoulder. This method has several undesirable features: The shoulder is fixed in adduction and internal rotation for prolonged periods, the elbow is immobilized,

FIG. 1

FIG. 2

Fig. 1: Pelvic platform brace in use: lateral view, showing essential details of construction.
Fig. 2: The shoulder is maintained in normal anatomical position and the hand and forearm are free for use.

the forearm and hand are subjected to atrophy of disuse because of this undesirable and unnecessary immobilization, and the opposite shoulder is forced by reason of the sling to carry the entire weight of the subluxated extremity. Frequently, the musculature of the shoulder girdle is involved, but to a variable degree. The patient with muscular weakness of the shoulder girdle, the neck, or the upper portion of the back is unable to support the weight of the upper extremity in a sling. To overcome these disadvantages a simple device was designed which allows the weight of the extremity to be taken by the heavy bone structure of the pelvis; hence, no additional strain is placed on the opposite shoulder.

The pelvic platform brace is a lightweight (one pound, four ounces) device, consisting of four essential parts:

1. Aluminum sheeting, lined with sponge rubber and molded to the contour of the hip;
2. A platform for the forearm of aluminum sheeting, lined with foam rubber or felt, and an adjustable hand rest;
3. An adjustable steel rod which attaches the forearm platform to the pelvic contour piece;
4. A web belt for maintaining the pelvic piece comfortably and securely in place.

Additional advantages of this type of support are that the forearm and hand of the involved side are free to be used and returned to a position of rest when desired, while the humerus and the glenoid cavity are held in a normal relationship. The shoulder is maintained in a neutral and normal anatomical position, not adducted and internally rotated as when held in a sling. The forearm and hand may be used at will for purposeful activities, such as eating and writing, while glenohumeral proximity is maintained by resting the elbow on the platform. There has been no difficulty whatever when the patient is seated, because the pelvic platform is above and lateral to the flexed thigh in the sitting position.

It has been our experience that the brace need not be worn at all times but may be removed for a period of a few hours daily without any untoward results. It is the prolonged and unrelieved traction at the shoulder which results in subluxation and, eventually, dislocation.

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(*Continued from page 655*)

The follow-up on the children revealed that they had no further complaints from the elbow. Normal use of the elbow continued. Each child was seen the day following reduction. There was no evidence of damage to the joint. No tenderness was present over the elbow.

One child, aged two, had a recurrence, one month following the initial injury, as a result of being lifted by both hands. The subluxation could be easily reduced and resubluxated by exerting mild traction of the arm with the hand in pronation. A circular plaster cast applied after reduction and worn for three weeks apparently stabilized the joint.

DISCUSSION

What changes occur in the joint in this condition is unknown. As the symptoms disappear immediately upon reduction and normal painless function is resumed the following day, it is probable that there has been no tearing of tissue. The annular ligament is probably stretched, allowing some fibers of the ligament to slip between the head of the radius and the capitellum of the humerus. Stone was able to demonstrate experimentally the slipping of the annular ligament over the radial head when the head was in pronation. White is of the opinion that the knoblike radial head is pulled through the annular ligament and is caught on the wrong side. It is highly improbable that any damage is done to the radial head. Spontaneous reduction undoubtedly occurs in many of the injuries, and only those which are "stuck" require treatment. Two additional children in whom the symptoms were typical as related by the mothers were treated "over the telephone". Symptoms in one child cleared up after an hour's sleep; gentle manipulation of the arm by the mother brought complete relief of pain to the other child and return to normal activity.

It is quite probable that spontaneous reduction would have occurred in several of these cases if the child had obtained the relaxation of sleep.

The differential diagnosis between this entity and a stretching of the brachial plexus with paralysis should not present a problem. The presence of pain on motion of the elbow joint and the rapid relief of pain on reduction by manipulation should make the diagnosis clear quickly.

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Proceedings

AMERICAN SOCIETY FOR SURGERY OF THE HAND

The Ninth Annual Meeting of the American Society for Surgery of the Hand was held in Chicago on January 22 and 23, 1954, preceded by a Clinical Day in Cleveland. The program for the Clinical Day was planned by Dr. Darrel T. Shaw, President of the Society, Dr. George S. Phalen, and Dr. Eldon C. Weckesser.

THURSDAY, JANUARY 21, 1954

Clinical Session at St. Luke's Hospital, Cleveland

The morning portion of the program consisted of the presentation of a large and interesting group of patients. The first group of cases, shown by DR. ELDON C. WECKESSER [1], consisted of three patients presenting the problem of congenital subluxation of the thumb which showed no evidence of active extension when first seen clinically. In the first case, seen when the child was nine years old, a fusion at the metacarpophalangeal joint was necessary in order to correct the deformity; whereas the other two who were babies, seen in the fourth to sixth week of life, responded well to conservative plaster-splinting and were found to show active extension of the thumb after approximately seven months of plaster-splinting. The other cases presented by Dr. Weckesser were those of ulnar-nerve and median-nerve paralysis secondary to crushing of the forearm, reconstruction of the thumb by iliac-bone graft and pedicle graft, avulsing wounds of the hand and the forearm, and the clinical results in the use of hydrocortisone following tenolysis of flexor tendons.

DR. GEORGE S. PHALEN [2] reviewed the problem of *Spontaneous Compression of the Median Nerve at the Wrist*, stating that he felt that this was primarily a neuropathy secondary to a rheumatic involvement of the synovial membrane. In none of the cases in which there had been a paralysis of the thenar muscles for longer than one year had there been any spontaneous recovery of this paralysis, even following the division of the transverse carpal ligament. Dr. Phalen pointed out a diagnostic test for this neuropathy and demonstrated that, with acute flexion of the wrist, the patient exhibits numbness and tingling over the median-nerve distribution in the hand.

Dr. Phalen also discussed the syndrome of *Calcification Adjacent to the Pisiform*. He suggested the treatment with local novocain injection into the calcified area in acute cases, and x-ray therapy in the severe acute cases, and pointed out that, unless one uses the proper x-ray technique, the pisiform cannot be brought into view for visualization of the abnormality. Dr. Phalen also discussed transfer of wrist extensors into finger flexors and showed a movie demonstrating two patients with "writer's cramp". The general consensus was that the "writer's cramp" was best treated by some psychotherapeutic approach.

DR. DARREL T. SHAW [3] presented several patients with congenital anomalies of the hand and discussed their treatment, as well as other patients with x-ray dermatitis and some with primary tendon repairs within the fingers, illustrating the use of the cross-finger flap. One interesting case presented by Dr. Shaw was that of a patient in whom a keloid-type scar had developed following an injury to the hand. The hand was treated by Z plasty; following the Z plasty, the same keloid scar developed again, but promptly disappeared early in the course of the patient's pregnancy.

Another interesting case presented by Dr. Shaw was that of Dupuytren's contracture in which, approximately two months after an excellent excision, acute swelling of the hand and considerable stiffness of the interphalangeal joints had developed. Another most interesting patient, in whom acute flexion contractures of all the fingers had developed following a head injury, showed an unusual result following a tenotomy and resuture of the interosseus tendons on both sides of the fingers, together with a resection and suture of the attenuated long extensor tendons over the proximal interphalangeal joints.

DR. SAMUEL G. STUBBINS [4] presented a case of trigger-thumb, as a congenital anomaly, which had not been corrected in early childhood and went on to produce a dislocation of the interphalangeal joint of the thumb.

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[2] Cleveland Clinic, Euclid and East 93rd, Cleveland, Ohio.
[3] 10465 Carnegie Avenue, Cleveland 6, Ohio.
[4] St. Luke's Hospital, Cleveland, Ohio.

Many other complicated reconstructive problems were demonstrated and much interesting discussion followed the presentation.

At the afternoon clinical session the following specific topics were discussed:

Pain. Dr. William A. Nosik [5] discussed the current concepts of the physiology of the peripheral nerves and their method of impulse transmission, together with factors which might be responsible for the production of some types of causalgia.

Sensory Disturbances in Reference to Conversion Neuroses. Dr. Louis J. Karnosh [6] stated that the number of diagnoses of sensory disturbances is gradually decreasing as a result of new physiological concepts with reference to nerve-impulse transmission. The discussion of the sensory disturbances in conversion neuroses was divided into causalgia, anxiety reaction, paroxysmal numbness, acroparaesthesia, and the restless hand and foot.

Hand Problems in Industry. Dr. Don A. Kelly [7] discussed the relationship of the doctor and industry from the standpoint of prevention and rehabilitation of hand injuries in the industrial worker. He stated that in 1952 there was an over-all cost of approximately $641,000,000.00 to industry as a result of hand and finger injuries. Eighty-five per cent. of all injuries to the hand and fingers were thought to be due to personal factors such as fatigue, horse-play, day dreams, or to poor selection of workers, or poor job placement. It was felt that there should be a greater effort on the part of the clinical surgeon to enlist the aid of industry in preventing the industrial accident, particularly in those plants where less than 500 people are employed and where, in most instances, there is no first aid or medical program. This is particularly important, since the employees in these small shops represent approximately 70 per cent. of the industrial workers in this country.

Recent Concepts of Burn Therapy. Dr. Johns H. Davis [8] discussed the "rule of nine" from the standpoint of body area, which allows one to calculate rapidly the percentage of the body burned. He presented an excellent outline of the fluid requirements in the first twenty-four hours of the acutely burned patient, describing in detail the so-called Evans formula, or the amount of colloid, electrolyte, and glucose and water which should be given.

Radiation Injuries. Dr. Donald M. Glover [9] discussed 150 radiation injuries. The treatment consisted in excision of the skin involved, frequently with the use of local anaesthesia and the application of split-thickness skin grafts. Of particular interest was the fact that many of the patients had had an interval of as long as twenty years between the time of initial radiation therapy and the time the skin changes had become so marked as to necessitate excision. Whereas split-thickness grafts were advocated for the dorsum of the hand, in some instances pedicle or full-thickness grafts were advised for the palm of the hand.

Emergency Treatment of Cardiac Arrest. Dr. Robert M. Hostler [10] presented a review of the history of cardiac arrest and then an estimate of the number of cases in which this complication occurs each year in the United States. Since it is estimated that this occurs once in every 1,000 cases of anaesthesia, it is not improbable that as many as 10,000 patients a year die from cardiac arrest.

The prevention is of primary importance; the lack of oxygen is probably the basic cause. In many instances the patient may come to the operating room over-sedated.

Once the cardiac arrest has occurred, one cannot allow more than three or four minutes to elapse from the time the heart has stopped until the oxygen system to the brain has been restored if one is to have success in restoration of the heart beat. In treatment, one must supply oxygen by intubation if possible, and establish an oxygen system to the brain by massage of the heart. Once this oxygen system has been re-established, then in the event that there is ventricular fibrillation, one can defibrillate the heart by electric stimulation of the myocardium.

Friday, January 22, 1954

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Digital Arthroplasty: The Proximal Interphalangeal Joint. Dr. Robert E. Carroll [11] and Dr. Thomas H. Taber [12] reviewed past attempts to restore motion to this joint, ankylosed in a position of deformity, and

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presented their method of arthroplasty. The report is based on the authors' experience with their first thirty cases. They point out that the proper selection of patients is essential and cannot be overemphasized. The operation is indicated when the deformity is considerable and disabling, when all tendons crossing the joint are capable of functional restoration, and if the patient's will to recover is of a high order.

Fracture of the base of the middle phalanx was the cause of the deformity in the majority of the series; fibrosis from dislocation or penetrating wounds had occurred in some; infection was responsible in others of the group.

Through a mid-lateral approach, the distal third, or less, of the proximal phalanx is exposed subperiosteally, sectioned transversely, and removed; the base of the middle phalanx is left as it is, regardless of deformity. Postoperatively, skeletal traction through a Kirschner wire, passed through the middle phalanx, is maintained by elastic bands for six weeks. A long and intensive course of physical therapy ensues.

The results have been classified as good when extension is complete or lacking not more than 10 degrees, when flexion of 55 degrees or more is present, and when there is no radial or ulnar deviation. Sixteen were given this rating. A fair result is one with a shorter but useful range of flexion; radial or ulnar deviation is present. There were nine in this category. In five no improvement resulted, and these were rated as failures.

Dr. Radford C. Tanzer [13], in discussing the problem, reported a case of ankylosis in extension treated by fascia lata arthroplasty with an encouraging early result.

Dr. Sterling Bunnell [14] pointed out that arthrodesis of the middle joint in semiflexion, with the finger a little short, results in a stable pain-free member which does not get in the way in flexion of the hand. He considered it, however, only a partial solution of the problem and hoped that the method presented by Dr. Carroll and Dr. Taber would bring improvement in our ability to cope with this condition.

Dr. William H. Frackelton [15] had performed resection arthroplasty in two children at the distal interphalangeal joint with good results.

Fracture of the Carpal Scaphoid Bone. Some Observations Based on Treatment by Open Reduction and Internal Fixation. Dr. Harrison L. McLaughlin [16] called attention to how little is actually known of the early changes which take place in the carpal navicular as a result of fracture. Roentgenographic findings, anatomical specimens, and experience with prolonged plaster fixation form the chief basis for what knowledge we have. Seldom is a fresh fracture of this bone examined. He called attention to the long period of disability resulting from this fracture for those unable to work with a plaster gauntlet. Open reduction in nineteen fractures encountered over a nine-year period had made possible some pertinent clinical observations and had permitted him to reduce the fragments and also to hold the fragments fixed with a lag screw while still allowing movement and use during healing. He had performed open reduction and lag-screw internal fixation in nineteen carpal-navicular fractures. Five were late cases, five were early cases without displacement, and in seven the fragments were displaced and unstable. Indications for operation included impracticableness of prolonged plaster fixation, displaced or unstable fragments, the fracture line through or proximal to the waist, and non-union without avascular necrosis or traumatic arthritis. The bone is approached through a curved incision extending across the anatomical snuff box proximally and dorsally from the base of the first metacarpal to the proximal end of the navicular. The radial artery is seen in the volar limits of the exposure; the superficial branches of the radial nerve are seen in the proximal limits. Disturbance of the capsular attachments to the distal dorsal tubercle or ridge of the bone is avoided except in a small area large enough to permit entrance of a small screw. The exposure provides a good view of both fragments and also makes it possible to glimpse the naviculomultangular joint for orientation.

His findings had indicated that "any displacement of the fragments was pathognomonic of gross instability", but "absence of displacement was not always synonymous with stability". In unstable fractures there was complete disruption of the articular cartilage. When the articular cartilage was broken, complete anatomical reduction could be neither obtained nor maintained by any manoeuvre or attitude of the hand, wrist, and forearm. Obviously external fixation could not immobilize the unstable fracture, nor was it apparent how healing could take place, since each slight thumb motion or compression moved the fragments.

Following reduction, the fragments are transfixed by a small Kirschner wire, the proximal fragment being held with a small skin hook or spoon. It may be necessary also to transfix the lunate. One tube of a double-tube guide is then placed over the projecting portion of the wire. Through the other tube a drill may be passed accurately across the fracture plane and well into the proximal fragment. Through this drill hole is then placed the Vitallium lag screw.

Cavitation at the site of fracture may occur in delayed healing or as non-union develops. Operative findings had failed to explain the mechanism of the decalcification. The mineral and soft elements of the bone were both absorbed. Healing may occur by proliferation of granulation tissue, and later this may be condensed into bone, and union may occur. In frank non-union the adjacent surfaces were polished smooth, covered with fibrocartilage, and bathed in joint fluid. Adhesions between the capsule and the margins of the

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fracture surfaces of the ununited fragments tended to reduce the mobility of the fragments. It was suggested that firm fixation by adhesions might explain why some patients with non-unions are asymptomatic.

With this operative technique, the average period of hospitalization was less than six days. In all but two cases, external fixation was omitted after a few days. Five patients with ununited fractures resumed their work at an early date, and have continued at work symptom-free. None of these fractures have united and probably none will unite. Five early stable fractures promptly united. Seven unstable early fractures also united, but did so more slowly.

In discussion, Dr. Harold B. Boyd [17] emphasized that results in fresh fractures of the carpal navicular are satisfactory when the fragments are adequately immobilized in plaster. However, the treatment may be extremely irksome and time-consuming. Noting that all distal fragments bled and none of the proximal fragments bled, he believed that probably the majority of the proximal fragments require revascularization.

Grip Test. The Use of a Dynamometer with Adjustable Handle Spacings. Dr. Charles O. Bechtol [18] presented a grip dynamometer with adjustable spacings which makes possible a more accurate evaluation of the force of the grip and of the effort made during the test.

The variations in the so-called normal grip are extreme. In the male, it varies between 60 and 130 pounds, and in the female, between 30 and 70 pounds. An occasional exceptional individual will go much higher. There are a considerable number of factors which influence the force of the grasp. The optimum size of an object is usually two inches for men and one and one-half inches for women. Exercise will increase the force of the grasp; however, this exercise must specifically require the use of the hand in grasping to significantly influence the grip. The major hand may be as much as 30 per cent. stronger than the minor hand, but a few cases are found in which occupation has reversed this, and the minor hand is stronger. There is a variation during the day. The grip in the middle of the afternoon may be as much as 20 to 30 per cent. stronger than that found early in the morning. Regarding effort, when the subject does his best, recordings will vary less than 20 per cent. and usually less than 10 per cent. Variations greater than these indicate lack of cooperation.

The observations to date indicate that there is a great deal of additional work to be done on grip in order to evaluate properly the disability of the employee and to place him properly on his return to work. This will require an additional detailed study of the forces of grasp necessary to carry out various occupations.

Discussing grip, Dr. L. D. Howard [19] stressed the voluntary nature of the effort made in gripping and called attention to the correlation between the forearm development on the affected and unaffected sides and the evidence of wear on the two sides of the palmar surface.

Dr. Daniel C. Riordan [20] reported that he had used the tester and found it valuable.

Hand Deformities in Hansen's Disease. Dr. Daniel C. Riordan [20] presented the clinical aspects of leprosy as it is seen in the United States and discussed treatment. Mild ulnar involvement may produce clawing of the ring and little fingers, and this may progress to involve the index and middle fingers. When the median nerve is also involved, these changes may occur in all five fingers, producing the claw-hand deformity. Intrinsic-muscle spasm may produce flexion at the metacarpophalangeal joints, hyperextension at the proximal interphalangeal joints, and flexion of the terminal finger joints (the intrinsic-plus deformity). Radial-nerve palsy may result in loss of wrist and finger extension. Finger deformities characterized by flexion of the proximal interphalangeal joints and extension of the distal joints are occasionally seen.

Prophylactic splinting and corrective splinting are used both preoperatively and postoperatively.

Operative correction of the claw deformities of the fingers due to ulnar-nerve loss, restoration of opposition in median-nerve involvement, and restoration of wrist and finger extension in radial-nerve paralysis are performed. Arthrodeses may have to be done when contractures have, through time, become fixed. Z-plastic procedures may have to be done for thumb-web contractures. Arthroplasties of the metacarpophalangeal joints may be indicated for dorsal contracture. Because of loss of sensation, the surgery may be performed without general anaesthesia or with supplementary local or block anaesthesia. Wounds usually heal well despite the lack of sensation.

Dr. J. William Littler [21], in discussing Dr. Riordan's paper, said that he had had opportunity during the past few months to see hands in various stages of deformity, secondary to median-nerve and ulnar-nerve paralysis. Last year at the meeting of this Society, Dr. Paul Brandt of Vellore, India, discussed this subject. He had used some of the types of transfers which Dr. Riordan showed today and some of those developed by Dr. Bunnell. In his description of lepers, it was shown that the main part of the ulnar nerve degenerates near the elbow and the median nerve degenerates near the wrist. Another point in Dr. Brandt's discussion was the interesting way he rehabilitated the lepers in his care. He found that rehabilitated hands, made usable by tendon transfer, might be difficult to use, because the patients had no sensation. He then went

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[20] 1538 Louisiana Avenue, New Orleans 15, Louisiana.
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further and found what blind people are doing. Knowing that the blind use their hands because they have sensation, he utilized for the lepers all those tasks in which sensation is less important but in which vision is necessary.

Experiences with the Steindler Flexoplasty at the Elbow. Dr. Leo Mayer [22] and Dr. Wallace Green [23] gave a detailed and complete description of the operation devised by Steindler and first published by him in 1919. Their experience with the operation extends over the past twenty years and their analysis is based upon twenty-two operations in twenty-one patients whom they have personally followed and whose results are known to them.

The operation is indicated for paralysis of the brachialis and biceps humeri in the presence of a strong medial epicondylar muscle group, especially the flexor carpi radialis and flexor carpi ulnaris. They consider satisfactory finger flexion indispensable; without good use of the hand, the procedure is contra-indicated.

In the absence of "good" medial epicondylar muscles, the Clark pectoralis major transplantation must be considered if that muscle is powerful. The authors suggest that time will tell which operation is preferable, the Steindler or the Clark. The occasion might arise when the Bunnell transplantation of the sternocleidomastoid to the biceps by the use of a strip of fascia lata might be advisable. The forward transplantation of the triceps, as devised recently by Dr. Robert Carroll, has been found to be effective, a transfer of power, which raises the question whether the sacrifice of the normal function of this muscle will be satisfactorily compensated.

The Steindler operation is considered a success only if the patient is able to bring the hand to the face, to do so gracefully without being made conspicuous, and if, at rest, the extremity hangs naturally at the side with the elbow flexed at not less than 165 degrees.

If the scapular muscles are strong, a flail shoulder is no contra-indication since, later, control may be re-established by arthrodesis.

The operation was described in great detail and with striking clarity. The incision allows ample exposure of the ulnar and median nerves and the anterior aspect of the distal humeral shaft. The transfer of all of the muscles of the medial epicondylar group, including the anterior portion of the flexor carpi ulnaris, is recommended.

The postoperative management is felt to be of the first importance. The patient usually leaves the hospital in two or three days. Flexion at the elbow is maintained for three weeks; if the triceps is paralyzed completely, this is reduced to two weeks. Stretching in the direction of extension is done gently by one thoroughly competent and is combined with exercises to develop the flexor group. Supination is stressed as an active exercise, and in this the patient is helped by exercises to develop the extensor pollicis longus and the flexor carpi ulnaris. After four weeks, a turnbuckle brace is worn at night to help win back elbow extension. The exercise-stretching-brace phase of treatment is absolutely indispensable, since without it a successful result can hardly be achieved.

Of twenty-two cases, excellent results rated at 95 to 100 per cent. were obtained in eleven; good or fair results, rated between 76 and 95 per cent., in nine; and poor in two. Too long a period of immobilization and triceps paralysis were the chief obstacles to a good result.

In discussing the operation, Dr. Arthur Steindler [24] reviewed the altered kinetics resulting from the operation, pointing out that to be effective the transposed muscles must operate with the wrist fixed. He recognized the tendency to cause pronation.

Dr. R. E. Carroll [11] spoke in favor of timing the flexorplasty so that it precedes any operative procedures directed toward restoring function in the hand. He based his opinion on his experience that tendon transplantations performed to restore hand function are more successful when the new points of origin of the transplanted muscles are already established. He felt that in that way the maximum functional gain would result.

Dr. William H. Frackelton [15] described a boy who had two paralyzed upper extremities, one of which was totally paralyzed, while the other had some power in the scapular muscles and flexor muscles of the forearm. The ability to eat by himself and to help dress himself had come following arthrodesis of the shoulder, flexorplasty at the elbow, arthrodesis at the wrist, and arthrodesis of the thumb in the position of opposition. The transplanted wrist flexors gave finger flexion to make possible useful pinch and grasp and flexion of the elbow.

Dr. Don L. Eyler [25] said that, in Dr. Mayer's modification, the internervous plane of Henry is utilized and, by insinuating a finger in this plane, one can carry the dissection proximally "with the grain" of the musculature without danger of damaging vital structures. By blunt and sharp dissection, a muscle mass made up of the flexor digitorum sublimis, palmaris longus, flexor carpi radialis, and superficial head of the pronator can be quickly mobilized and the common aponeurotic origin can be freed from the medial epicon-

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dyle. The dissection is relatively avascular, the median and ulnar nerves and ulnar artery are plainly visible at all times, although no special dissection or attempt is made to expose them, and a large mobile mass of muscles is available for transfer. He complimented Dr. Mayer on his presentation and paid due respect to Dr. Steindler who fathered this ingenious procedure.

The Care of Injuries of the Hand and Fingers with Special Reference to the Treatment of Traumatic Amputations in the United Kingdom. Mr. Patrick Clarkson [28], honored guest of the Society, gave an interesting account of the treatment of open injuries of the hand, seen the day of the accident, in the Hand Clinic established in Guy's Hospital, London. Of 11,000 accidents treated each year in the Hospital Clinics, about 3,000 are injuries to the hand. The upper limb below the elbow is the most commonly injured part as seen in most hospitals in densely populated cities with light industries; these injuries account for one third to one half of the total accidents to be treated. Most of these are minor injuries. Less than 10 per cent. of these patients had fractures, and less than 1 per cent. required admission to the hospital. Only about 200 presented problems in skin repair, requiring free grafts or flaps.

Mr. Clarkson drew a sharp distinction between lacerations due to cutting injuries and open contusions caused by crushing violence, such as those seen after the part has been caught in a power press. The latter are far more serious, not alone because of the frequent bone and other deep-tissue complications, but because of the oedema which usually follows during the first twenty-four to forty-eight hours and the indeterminate extent of the injury at first. While the incised wound may heal in one week, the open contusion may require two or three weeks. Thin split-thickness-skin graft cover for contused tissues is preferable to closure by approximation of edges which may lead to serious complications. These free grafts are relatively unsightly and poorly sensitized, but they are much more reliable and may be done by a surgeon of less experience than is necessary for a full-thickness skin graft.

Formal treatment in a fully equipped operating room is accorded all breaks of full skin thickness. Tetanus serum is given all who have not had toxoid or who have no allergic complaints. Penicillin is given prophylactically only when wounds are grossly soiled or the repair has required more than one hour. Thorough toilet is performed, primarily, from the elbow down, when possible by the patient. After local analgesia, a secondary toilet is done by the operator. Local analgesia is used in over 99 per cent., over 15,000 local blocks having been done without complications. The use of adrenalin is avoided. When the wound is an incised laceration, minimal excision followed by the approximation of edges is practised routinely. Lavage of open contusions with excision of only grossly soiled or obviously devitalized tissue is practised at primary operation, tissue of doubtful viability being left. Free grafts, used at primary repair, are limited largely to thin split skin taken from the forearm in men and from the thigh in women. Cross-finger, palmar, and thenar flaps are used occasionally.

The results support the position that there is a fundamental difference in the healing rates between the lacerations and the contusions. The lacerations showed a mean healing time of eight days; the open contusions showed a mean healing time of seventeen days. These rates appear to represent a reasonable standard. The survey shows, however, that there were some which did not completely heal for many weeks. The mean healing time, when there was soft-tissue loss, was nearly a month. There happened to be no major infections last year.

Minor infections in 1,800 lacerations without soft-tissue loss came to 0.3 per cent.; with soft-tissue loss to 5.7 per cent. Minor infections in 220 open contusions without soft-tissue loss came to 1.8 per cent.; with soft-tissue loss to 4.3 per cent.

Traumatic amputation of the digits was discussed under two headings: primary treatment and digital reconstruction by pedocarpal transfer. Primary treatment requires a choice between covering the stump with a thin split-thickness skin graft or by a thenar or palmar flap. Occasionally one may consider suturing back the part amputated, or re-amputating at a proximal level.

Salvaging an amputated part is practicable only when less than half the distal phalanx is involved, and it is seldom successful. Proximal re-amputation is done only when extensive proximal injuries make it clear that the part to be further sacrificed has no future usefulness. Thin split-thickness skin grafts take dependably, but they are not well sensitized and are unsightly. Their use has been limited to the medial three digits and to elderly patients. When bone is exposed, this is beveled anteriorly to allow pulp to come in contact with the nail bed. Thenar and palmar flaps when necessary are felt to give the best primary repair. The secondary defect is best covered by a full-thickness skin graft, cut to pattern. Such repairs have not resulted in stiff fingers, and there is better sensation.

The method of late total reconstruction of digits by transferring toes was described in detail. A delayed dorsal flap on the donor foot is used. When the hand is attached to this flap, the extensor and flexor tendons of the toe are attached to the corresponding tendons of the forearm. The hand is left attached to the foot for six weeks. The digital vessels are divided at the second and fourth weeks. Mr. Clarkson had transferred fifteen digits in six patients and had lost, through a technical error, only one half of one digit in a three-digit transfer. He knows of two other successful transfers.

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Dr. Michael L. Mason [27], in discussing Mr. Clarkson's report, remarked on the fewer lacerated wounds and the higher proportion of crushing injuries seen in the hand clinics of this country, as compared with those seen abroad. He prefers local infiltration anaesthesia to digital block, since he has in the past seen necrosis with the use of the latter. Reluctant to use palmar flaps on account of scarring, he usually places the finger tip in a flap from beneath the breast or from the abdominal wall. He agreed that cross-finger flaps have a place.

Dr. J. Edward Flynn [28] reported a comparable series of hand injuries treated at the Boston City Hospital. In 612 compound injuries subjected to treatment over the past five years, there have occurred three cases of major sepsis and six of minor sepsis — an incidence of 1.5 per cent. He has used pedicle grafts from the thenar area to cover partial amputations of the distal phalanges of index, middle, and ring fingers, the bone being exposed and hypothenar flaps being used for little-finger-tip coverage. Thumb-tip coverage has been obtained from the dorsum of the middle phalanx of the index finger. There has not been trouble from the thenar flaps, provided that the graft was properly placed, a full-thickness skin graft was applied in the donor defect, and the pedicle was detached in twelve days. When pedicle-graft coverage is not used on amputation tips, the digital nerves are ligated and are transplanted beneath the dorsal skin.

Capsulectomy of the Interphalangeal Joints of the Fingers. Dr. Ray M. Curtis [29] discussed the mechanical factors which may limit flexion and extension in the interphalangeal joints and presented an operative technique for the correction of the contractures which result from them.

Extension contracture of these joints may result from scar on the dorsum of the finger which will limit flexion, regardless of flexion or extension at the wrist or of metacarpophalangeal joints. When flexion is limited by a contracted long extension muscle or an adherent extensor tendon, dorsiflexion of the wrist or extension at the metacarpophalangeal joint will release the joint, thus allowing flexion. When intrinsic-muscle contraction is present, extension at the metacarpophalangeal joint will hold the muscle tense, preventing flexion at the interphalangeal joints; when the muscle is released by flexion at the metacarpophalangeal joints, the interphalangeal joints may be flexed. When the capsule is contracted, the interphalangeal joint is stiff, regardless of the position of the metacarpophalangeal joint.

Limitations in extension are less easily analyzed. It is often not possible to differentiate between a flexion contracture due to an adherent flexor tendon, a contracture of a flexor-tendon sheath, or a capsule contracture.

Operative correction is resorted to only when splinting and physical therapy have failed to restore sufficient finger flexion or extension. In the operation, the joint is approached from each side through longitudinal, medial, and lateral incisions. The deep fascia is elevated, and the joint capsule is divided beneath it transversely or a wedge or block of the ligament is excised on either side at right angles with the long axis of the finger. When indicated by lack of flexion, the capsule may be farther divided dorsally; or, when limited by flexion contracture, it is divided on the volar side. Stability at the proximal interphalangeal joint has been maintained through preservation of the deep fascial cuff. At the distal interphalangeal joint it had not been possible to preserve the deep fascial cuff; yet no instability had resulted from division of the collateral ligaments or of the volar plate. When found to be obliterated, the volar synovial pouch may be reshaped with a small curved elevator or by forced flexion. When there is associated interosseus contracture, the interosseus tendon is lengthened and sutured; if necessary, the extensor mechanism may be freed.

At the close of the operation, one cubic centimeter of hydrocortone is injected into the joint. The flexed position is maintained by a fine Kirschner wire, which is removed in five to seven days. Rubber-band splinting is then started. When extension is being restored, the rubber-band splinting is begun immediately.

From his experience with sixty-six interphalangeal joints upon which he had performed the capsulectomy, Dr. Curtis concluded that, when the interphalangeal joint is "intrinsically in good condition as shown by the roentgenogram", a measurable improvement may be expected from the operation and at the same time stability will be maintained.

In discussion, Dr. Sterling Bunnell [11] stressed that a joint long flexed will not extend until both collateral ligaments have been excised and the volar ligament has been divided. The same is true of a joint long in extension: the collateral and dorsal ligaments must be cut. However, if too much capsule is excised, dislocation will occur. He felt that Dr. Curtis's use of the deep fascial sleeve might prove well worth while.

Dr. Emanuel B. Kaplan [26], in discussing the problem of instability following interphalangeal-joint capsulectomy, expressed the opinion that instability can be avoided if the dorsal structures about the joint and the flexor tunnel are preserved. He advocated incising the deep fascia longitudinally and retracting the extensor mechanism, thus freely exposing the joint. After the appropriate division of ligaments and capsule, the extensor apparatus is replaced. He favored skeletal traction postoperatively.

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[26] 1001 Grand Concourse, Bronx 52, New York.

Experimental Nerve Repair in the Dog. Dr. Richard I. Gonzalez [31], in an effort to determine more accurately the healing time of primarily repaired nerves, had devised an experimental method in dogs by which the tensile strength was ascertained in grams per square millimeter at daily intervals following repair. His report concerns a preliminary series of forty-four experiments, covering the period from the day of repair to twenty-two days following repair. In this series it appears that the nerves attain their original strength in ten days after suture and attain a strength superior to the adjacent normal nerves in eighteen days. If the final series of 150 experiments bears out these preliminary findings, the clinician should be able to shorten the presently accepted period of three weeks' immobilization following nerve repair.

In the discussion which followed, Mr. Patrick Clarkson [28] asked whether the stress applied in the testing is sudden or gradual, a matter of importance as far as the management of these cases goes. He said the matter of primary and secondary repair was discussed at the Royal Surgical Society, and Mr. Seddon and others held to a view, which is not generally accepted, that secondary repair gives a better end result. Their reasons for holding that view were that almost any injury causes more lateral contusion in the body of these nerves than is caused by the direct result of the blow, and consequently secondary repair after the inflammation has subsided gives a better result. They believe that the lateral contusion prejudices primary repair and so affects it that the end result is less satisfactory than after secondary repair. An additional reason they advanced is that, in experimental observations of primary repair, attaching pieces of metal foil to each side has often demonstrated changes which are definitely opposite to those which would be expected from Dr. Gonzalez's results. He felt sure that in the United States more than in any one place in England better results are obtained after primary repair.

Dr. Leo Mayer [27] suggested that two or three weeks be allowed to elapse after section before repair is made and then the results be compared with those found in the present series.

Dr. Gonzalez, in closing the discussion, said his tests were done under acute stress over a period of minutes. He felt that Dr. Mayer's suggestion was valid. In these cases, he had been struck with the anatomical differentiation of the nerve sheaths. Many have said that sheath-to-sheath repair is impossible because the sheath is such a delicate structure. He had found it is a good structure as demonstrated by the tensile strength of the nerve immediately following repair. Clinically, his results had been equally satisfactory whether the nerve was repaired primarily or secondarily.

Dr. Darrel T. Shaw [3] drew a correlation between healing wounds of the nerve and wounds of the skin or other recently formed fibrous tissues. He felt that they are not so resistant to chronic stress as the tensile-strength experiments of Dr. Gonzalez's report would indicate. Chronic stress will cause separation of newly formed scar tissue.

Arterial Vascularization of the Soft Tissues of the Palm. Dr. Herbert Conway [32] and Dr. Richard B. Stark [33], having noted that a slough of the soft tissues or a delay in the healing of wounds in the central part of the palm occurs sufficiently often following surgical intervention, investigated the quantitative degree of vascularity of this zone.

Radiopaque fluid (thorium dioxide) was injected into the radial and ulnar arteries of both upper extremities of five cadavera from the dissecting room. The skin and subcutaneous tissue were dissected cleanly from the deep fascia and palmar aponeurosis, and arteriograms were made of the soft tissue removed.

The material showed that the arterial vascularity of the skin and subcutaneous tissue of the palm of the hand is supplied through the superficial volar arch by means of numerous small vertical tributaries perforating the skin. Richly vascularized areas of the palm include the thenar and hypothenar eminences and the palm on the digital side of the distal flexion crease. However, in the central portion of the palm, bordered by these areas of marked vascularization, there is a triangular zone of skin and subcutaneous tissue which exhibits a paucity of arterial channels. This has been found to be constant in ten palms of cadavera.

They pointed out that the skin and subcutaneous tissue of this area are undermined widely in the technique of complete palmar fasciectomy. The poor arterial supply of the area undoubtedly explains why a slough of the palmar skin is encountered occasionally following operation for Dupuytren's contracture. It is felt by the authors that the extent of undermining of the flap of skin and subcutaneous tissue should be limited if slough of the flap is to be avoided. Limited reflection of this flap means that only a limited excision of the palmar fascia can be achieved. However, by use of a short Meyerding-Bunnell curvilinear incision, the palmar aponeurosis to the long, ring, and little fingers can be approached with ease. By the use of this incision, the palmar fascia may not be divided so far proximally as its attachment to the palmaris longus, but involvement of the proximal portion of the palmar fascia in the disease process of Dupuytren's contracture is extremely rare. This limited palmar incision makes difficult also the approach to the fascia over the index finger, but this digit was involved in the disease process in only 11 per cent. of eight-eight cases of Dupuytren's contracture treated at the New York Hospital.

The alternative to limited undermining of the skin and subcutaneous tissues and limited excision of the

[31] 111 St. Matthews Avenue, San Mateo, California.
[32] 525 East 66th Street, New York 21, N. Y.
[33] 200 East 68th Street, New York 21, N. Y.

palmar aponeurosis is complete removal of the palmar aponeurosis with removal of skin of questionable viability, and its replacement with grafts of whole-thickness skin or with pedicled flaps.

They conclude that the central palm contains a triangular zone which is poorly vascularized. Because of the quantitative paucity of blood vessels, extensive undermining of this flap may invite delayed wound healing or frank necrosis. Appreciation of this important anatomical weakness has led the authors to adopt the principles of limited undermining of the skin and subcutaneous tissue of this zone or their primary excision and replacement with whole-thickness skin grafts or pedicled flaps following undermining of an extensive degree.

In discussion, Dr. Hans May [24] pointed out that all those who have done operations for Dupuytren's contracture or are interested in the pathology of this condition are aware of the fact that a diseased fascia not only sends extensions into the overlying skin, but also into the deeper tissues whereby the digital nerves and vessels gradually become involved and constricted. Lexer, who devised the first radical operation for Dupuytren's contracture, advised (1) the removal of the entire diseased fascia and also that part of the overlying skin which is involved in the process, in order to remove a possible source of recurrence, (2) the removal of a part of the skin which has impaired circulation, and (3) the creation of sound vascular conditions upon which a skin graft can regenerate. Dr. May had had no reason to regret a radical procedure and had become an advocate of such an operation. He was in full agreement with Dr. Conway and Dr. Stack that regional excision of the diseased skin in Dupuytren's contracture and replacement of the same with a skin graft is in order.

Dr. Conway, in closing the discussion, stated that the studies reported are part of a study which he and Dr. Stark have been carrying on for the past year. The subject of surface vascularization has been relatively neglected since the latter part of the nineteenth century when Manchot published his classic monograph. His work was the result of dissections on cadavera. In the study reported, radiopaque material was injected into cadavera and arteriograms were made of the skin and subcutaneous tissue of various parts of the body. The circulation thus outlined emphasizes the consistent elongated axes of cutaneous circulation which should be considered in the formation of long flaps and pedicles. It has become evident that this chronic disease, palmar fibrosis, is due to fibrous contraction of the palmar aponeurosis and the overlying skin and subcutaneous tissue which results in a diminution of the arterial blood supply. Their investigations had disclosed a zone in the central part of the palm which is consistently less vascularized than the area surrounding it. Certainly a palmar slough, due to fibrous contracture, superimposed upon this zone of anatomical weakness creates a critical deformity. Whether this zone, turned back as a flap, should be replaced by a skin graft, as Lexer did many years ago, is a matter of surgical judgment. A graft of the palm is certainly superior to palmar necrosis or delayed wound healing. He felt that the operation for Dupuytren's contracture is one which should not be entrusted to the surgeon in training without total supervision. This vascular study upon the total body is to be continued.

Saturday, January 23, 1954

Clinical Session, Northwestern University Medical School

The Organization of Hand Services in Teaching Hospitals. Mr. Patrick Clarkson [25] commented on the organization of a hand service, particularly in teaching hospitals. He felt that the objectives of a hand service in a teaching hospital are: first, to obtain a high general standard of result and, second, to make the optimum use of the abundant clinical material for the teaching of students and interns in principles and basic techniques of reparative surgery.

He felt that responsibility for control of the accident service can very adequately be allotted to a general, an orthopaedic, or a plastic surgeon. It is essential, of course, that he be well versed in the basic plastic techniques of repair necessary for the common and important injuries to the hand, which constitute the major part of the clinical material passing through the department. Whatever the chief clinical interest of the head of the department may be, it is desirable that he have work outside the casualty and accident department. If he is an orthopaedic or plastic surgeon, he should be attached to special centers where the major long-term repairs of gross and complex hand wounds are chiefly done.

Regarding the treatment of hand and finger infections in casualty departments, he felt that the subject is no longer a major one in hand surgery. He reported that one does not now see, in England, either the number of hand infections that were formerly seen or the same range of type and severity of cases as previously.

About the special infections, in 1953 there were nearly 900 infections of the hand. There were no patients with special infections admitted to the wards. There were under ten cases of swine erysipelas. It is many years since there has been a syphilitic infection of the hand seen in the department. Since the War there have been two cases of anthrax.

Acute diffuse infections have been conspicuously absent. For several years even lymphangiitis has been rare. In this group of nearly 900 cases, there were only two thecal infections and only two deep palmar

[24] 255 South 17th Street, Philadelphia 3, Pennsylvania.

abscesses. The other infections have been chiefly pulp-space and other subcutaneous abscesses and paronychiae. The principles of treatment are: rest of the part in the position of function (not the position of rest) during the invasive period of the first three to five days only; evacuation of localized pus by a small incision which inflicts no functional disability to the hand and which is combined with removal of obviously dead soft tissues in the abscess walls, and preservation of function by active movements of non-affected digits.

Penicillin is given in most cases, but not in the less severe cases. The routine dosage is three daily injections of 300,000 to 600,000 units of penicillin procaine.

An investigation has been conducted of the value of primary excision and suture of pulp-space and other subcutaneous abscesses, except those in the web spaces. We have seen no disasters following this treatment, which is based on the concept that there are two pus-producing mechanisms—bacterial activity and dead tissue. If penicillin takes care of the first, and minimal but meticulous excision of dead tissue is done at the time of primary drainage, then the abscess cavity can be obliterated by suture. A few patients have had to have the sutures removed and drainage re-established, but the group as a whole appear to have done better than the larger group treated by orthodox methods. It must, however, be remembered that these cases have been subjected to special study and attention. The method is not advocated in routine teaching, but it deserves further study. Attention should be drawn to the apparent increased rate of skin healing which is repeatedly observed in these cases.

The discussion was opened by Dr. Edward Flynn [25] who asked Mr. Clarkson if he had had any experience with the local use of penicillin for acute suppurative tenosynovitis and deep fascial-space infections.

Mr. Clarkson replied that he could not give an authoritative answer because he saw no more than two deep palmar abscesses a year. The pus is evacuated by incision. Obviously antibiotics play a big part in the success of treatment.

Dr. Sumner Koch [35], noting that very few of Mr. Clarkson's patients were admitted to the hospital, that in only a very limited number did infection develop and that healing took place in from seven to ten days after drainage of an infected wound, reported that rarely were such good results secured on his service. He recalled that there were 3,000 cases of injury of the hand cared for in Guy's Hospital during 1953. If one omits Sundays, there would be an average of nearly ten cases a day. He wondered who was taking care of this large group of patients and how a staff caring for such a large number of cases, almost all as ambulatory patients and not under close supervision in the Hospital, could secure such excellent results and with almost no wound infections. Such results he had not been able to accomplish. He simply wished to know why he could not secure as good results as those which have been reported by Mr. Clarkson.

He wished to know also how often and by what method antibiotic therapy was given when practically all the patients were ambulatory and not kept in the Hospital after their initial care.

Mr. Clarkson thanked Dr. Koch for giving him further opportunity to make clear that the vast majority of the open hand injuries reported had been small injuries. A great number would have healed without complication by conservative treatment with a simple dressing, without surgery. But the whole point of the organization has been to teach that every breach of the full thickness of the skin of the hand should be given full, formal treatment in an operating theater. The numbers reported might appear large, but he wished to emphasize again that these are unscreened cases; the patients attend without payment and use the Hospital as a sort of general practitioner. They represent the total for seven days a week, twenty-four hours a day, the whole year round. The daily number may vary between five and fifteen.

About the incidence of infection following the primary repair, an infection is considered major when the patient goes home after repair but comes back in a day or two with pain, fever, and gross infection in the wound, necessitating immediate removal of the sutures and drainage. The expectation is that about one in a hundred injuries will behave like this; but last year there were none. Minor infections are those showing pus on the dressings or around the sutures and delay in healing. These can be very serious in terms of economic disability and the quality of the eventual scar. Drawing attention to his charts showing the healing rates of the lacerations and of the open contusions, he pointed out that there is a considerable scatter to the right of the mean healing days of eight and seventeen, respectively, of the two lesions. This indicates many results which Dr. Koch would call very poor indeed; in a number, he regretted, healing took several weeks and in some three weeks and in some three or four months. Indeed the average healing time for the lesions with soft-tissue loss needing repair by flaps or free grafts was about a month—a figure on which he, and indeed anybody, would hope to improve.

About antibiotic treatment, Mr. Clarkson said that most patients are given antibiotics as a routine measure, three to four daily doses. It is possible that, when they attend the injection room simply for injection and not for attention to the wound (which may be left undisturbed for intervals of two to five days), this is not reported as a separate attendance; but the figures in the chart of mean healing days and mean attendances are a very fair picture of treatment given and results.

Dr. Thomas W. Stevenson [36], recalling that, in his reconstructive care of the hand, Mr. Clarkson frequently permits the patient to go home after the application of a graft, expressed dislike for having the pa-

[35] 154 East Erie Street, Chicago 11, Illinois.
[36] 180 Fort Washington Avenue, New York 32, N. Y.

tient out of his control in the early period, when various accidents of normal living can occur. He felt that, when he had taken necessary time to put on a graft, he was obligated to safeguard the patient from an infection of the hand. Also, it is certain that dressings are less subject to derangement while a patient is at rest in a hospital and that elevation is beneficial to healing. On the other hand, it is obvious that Mr. Clarkson has obtained good results with early ambulation. Therefore, he felt that perhaps it would be well to take another look at the question. It certainly would relieve the demand for hospital beds if we could strike a happy medium.

In closing, Mr. Clarkson stated that, if a patient can be successfully treated as an out-patient without courting unnecessary pain or risk, it is economically sound that this should be done.

Presentation of Cases of Nerve Injury. Dr. Michael L. Mason [27] presented cases illustrating the first problem, that of repair of the nerves of the hand. He hoped that this might bring out discussion of the indications for primary *versus* secondary nerve repair, the feasibility or indication of primary repair in the acute open injury, or the view that these wounds should be closed and a secondary repair done later on, one of the big problems in the treatment of nerve injuries today.

The first patient represented a frank problem in secondary nerve suture. She was first seen in May 1947, when she was a little girl, sixteen hours after she had lacerated the left wrist. The wound was open and a short incision had been made in it to find the ulnar nerve. It was felt at the time, because the wound was sixteen hours old, that the primary suture of the nerve was not indicated. The wound was simply sutured; a secondary closure was carried out as he had learned to do while in Service. In August 1947, the wound was reopened and the ulnar nerve was repaired, both the main trunk and the dorsal trunk. The wound healed kindly. It is now nearly seven years since secondary nerve repair. The girl has gradually regained the use of the small muscles of the hand, and sensation is normal. She cannot adduct the little finger. That is the last thing to be regained and is often never regained even with otherwise complete recovery. Why?

The next patient, a man, had been in an automobile accident in May 1952, at which time he had sustained a laceration of the left elbow and a fracture involving the lower end of the humerus. The wound had been sutured elsewhere at the time, but immediately after the injury it had been noted that he had an inability to extend the wrist and forearm. He had drop wrist and fingers. He was seen first in August 1952, at which time a radial-nerve injury was diagnosed. The incision was made through the original scar, the ends of the radial nerve were found and brought together. A splint was applied, holding the wrist in extension, with elastic traction to the digits. This splint makes it possible to flex the fingers and to use the hand while the patient is recovering from the radial-nerve paralysis. He is a dairy farmer. He has good use of the hand, but he still cannot do milking.

Another problem this brings up is whether in an instance of this sort it would be wise, instead of having the patient wear a splint for a long period of time, to do a tendon transplantation at the same time as the nerve repair. If the nerve function does not come back, the patient still has the possibility of extending his hand and fingers.

Another man had been injured in June 1953, at which time he had cut his forearm on a meat saw. A primary repair had been carried out and the wound had healed kindly, but the hand had been held in acute wrist flexion in a splint for thirteen weeks. When first seen in this Clinic he had a severe volar contraction of the wrist and inability to flex the index finger, thumb, and middle finger. A long time was spent in physical therapy, getting the wrist back into extension and getting the tissues soft. In November, the forearm was re-opened through an S-shaped incision and the median nerve was found to be divided, the ends being bound in a dense scar. The flexor profundus and the flexor sublimis to the index and middle fingers and the flexor pollicis longus had been divided. Nerve and tendon repair was carried out, the profundus tendons to the index and middle fingers being sutured, the sublimis tendons to these fingers being removed, and the flexor pollicis longus being repaired. Following that procedure, the wrist was put up in flexion. He was presented because of the fact that his thenar musculature is perfectly good. He can swing his thumb around to face the palm, in spite of the fact that the median nerve was found to be completely divided at the time of injury. Not infrequently the thenar musculature is innervated, often through the ulnar nerve by way of branches which anastomose in the arm from the median to the ulnar nerve. By means of these anastomoses or intermixing of fibers, it is possible to have complete division of the median nerve above the wrist and still have motor fibers to the thenar musculature.

The next patient was seven years old in 1949. At five o'clock one afternoon he had put his hand through a plate-glass window and had sustained a laceration across the volar aspect of the wrist. At eight o'clock that evening he was in the operating room. There were found lacerations of both flexor tendons of the wrist, the ulnar nerve, and the profundus tendons to the index, middle, and ring fingers. All of these structures were repaired by primary suture.

Dr. John Bell [27] presented nine additional cases of nerve injury.

One patient had been in an automobile accident in October 1952, and had sustained a head injury and

[27] Northwestern University Medical School, Chicago 11, Illinois.

a closed fracture of the left humerus. She was first seen in this Clinic in January 1953, when she gave a history that the fractured humerus had been treated with a hanging cast until December 1952, and she had had loss of extension of wrist and fingers since seven days after the injury. There was complete radial-nerve palsy. On January 30, 1953, the arm was explored, and the radial nerve was found to be caught over the distal fragment of the humerus which was ununited. The nerve, which looked normal, was freed and the tension was thereby relieved. A bone plate was applied and bone chips were placed about the fracture site. Within twenty-four hours after operation, she began to have some slight return of function of the extensor muscles. By June 1953, six months later, she had almost complete return of function of the muscles controlled by the radial nerve.

A child was admitted to the Cook County Hospital on January 1, 1953, after he had sustained an open fracture of his humerus at home. He was put in traction for twenty-nine days. It was noted that he had a radial-nerve palsy during this course of treatment. He was seen in the Hand Clinic at Cook County Hospital in April 1953, and was admitted to the Hospital. An exploration of the previous wound was performed, and it was found that the radial nerve was imbedded in the callus of the healed fracture. This was freed and he has nearly regained function in the radial nerve.

A boy, aged six, fell on a milk bottle in August 1951, and was admitted to the Cook County Hospital. He had a primary closure of his skin wound. He sustained a laceration of the left ulnar nerve above the elbow. In September 1951, he was admitted to the Hospital from the Hand Clinic. The ulnar nerve was exposed in the elbow region and was found to be completely divided. The neuroma was excised and the nerve was sutured. The ulnar nerve was transplanted anteriorly to the medial condyle. He has had an excellent return of sensory and motor function following the secondary nerve suture.

During the discussion, Dr. William H. Frackelton [10] recalled the presentation of Dr. Ernest Miller in Milwaukee and his wide experience with high-tension burn cases. Dr. Miller believed patients had an osteoperiostitis which was a cause of pain in the burned limbs persisting for years. He asked if anyone could tell him of any recorded studies of primary suture and secondary suture in electrical potential burns.

Dr. J. Leonard Goldner [25] replied that he could relay the opinion of one of his colleagues, Dr. Barnes Woodhall, who has done much clinical and investigative work relative to nerve repair, and his ideas are about the same as those expressed by Mr. Clarkson. He agrees with the principles of Mr. Seddon and is in favor of secondary repair. At Duke Hospital, a primary nerve injury is seldom seen, but frequently deformed hands with contractures are seen, in which primary-nerve repair had been done by the surgeon who saw the patient initially. It is the same old question of a traumatic injury being treated during the late hours of the night, the question of how much tissue has been destroyed, inadequate operating-room help, and no time to review the anatomy, with resulting secondary infection and an inexact repair. The primary repair of tendons is another matter, but again, if the circumstances are extenuating, it is desirable to close the wound and to do the repair under ideal conditions.

One patient has been shown at this session who has good opposition of the thumb in spite of the median-nerve laceration. Dr. Goldner's experience has also confirmed this observation but, in most of these cases, there is still paralysis of the opponens pollicis and that is true in this particular case. Moreover, the abductor pollicis brevis is frequently paralyzed, but the weakness in these muscles is compensated for by a strong palmaris longus, a contracted flexor pollicis longus, and a strong flexor pollicis brevis. One must recognize the absence of pronation against resistance and the fact that the patient can pinch and grasp, but that he does not have true opposition. He asked for opinions concerning radial-nerve paralysis in conjunction with a fracture. When should one look at the nerve?

Dr. Mason replied that he has to treat the radial nerve after the fracture has been taken care of elsewhere, and the patient comes in with a wrist-drop. That decision does not often come up.

Dr. Goldner then raised a question which comes up frequently. Should tendon transplantation be done for radial-nerve paralysis prior to the period of five or six months necessary for regeneration of the nerve, or should one wait the usual twelve or eighteen months necessary for the entire muscle strength to return? Occasionally, of course, the nerve damage will be irreparable and early tendon transplantation is justified. He had seen one patient who had a tendon transplantation at the time of the nerve injury. Although the nerve was in continuity, the surgeon decided to do the transplantation in order to aid rehabilitation. The transplant worked well, and at the end of a five-month period, the brachioradialis and the other extensors showed evidence of re-innervation. As the muscles improved in strength, the hand and wrist went into a fixed dorsiflexion deformity. An effort was then made to tape down the transplant and, although this was partially successful, there was so much structural shortening that the patient never did regain full volar flexion. There is considerable danger in carrying out primary tendon transplantation in radial-nerve injuries. A minimum of six months should elapse in radial-nerve injuries; the minimum of six months should elapse before tendon surgery is considered. Substitution for the paralyzed opponens is an entirely different matter. Even if the opponens and the other finger muscles show complete regeneration, there is little disability from the transferred tendon.

Dr. Sterling Bunnell [11] felt that, if a nerve is sutured primarily, it will come back faster and better

[25] Duke Hospital, Durham, North Carolina.

than if the suture is done secondarily. Therefore, if the nerve can be repaired well, it should be done. If the nerve injury is to be managed by the general practitioner in a small town, it is far better for him to fasten the two ends together with one stitch of stainless-steel wire so they will not retract; a secondary suture may then be done later in a suitably equipped clinic.

There is an idea prevalent throughout England that one should not suture a nerve primarily, but should wait twenty-one days, because one cannot tell how far back the neurons are destroyed. In crushed or explosive wounds, they are destroyed farther back than in lacerated wounds. Therefore, since primary suture well done gives the best results, all that is necessary in primary suture soon after the accident is to cut back the nerve ends farther in explosive and crushed wounds and to suture them primarily.

As to overcoming gaps in nerves, it has been stated that ten centimeters is all that can be overcome. One can successfully overcome fifteen centimeters. One reason that ten centimeters is given as the limit is because it was formerly customary after three weeks to allow the limb to be extended little by little. Three weeks is not long enough before starting to open the joints. It is true that the nerve juncture is quite firm as tested by spring balance in three weeks, but that does not take into consideration that scar tissue under steady traction will stretch after three weeks. Therefore, it is better to wait a full month after nerve suture before exerting tension on the nerve to make it grow longer. In exerting this tension, the snub method is the best. If a turnbuckle or wedge-cast method is used, sooner or later the nerve will be placed on tension. That will mean ischaemia which, of course, results in necrosis and eventually fibrosis. By the snub method, the nerve is let out little by little twice a week, according to the feeling of the patient. Then it is snubbed by the splint to avoid further tension. The arm is, however, left free to flex at both elbow and wrist. Therefore, when the patient has an uncomfortable feeling, he will flex his elbow and wrist and thus relieve the ischaemia on his nerve. The nerve is not to be stretched longer (it cannot be), but it is to be persuaded to grow longer.

Dr. J. Edward Flynn [28] raised the question: When repairing a lacerated radial nerve, should one perform tendon transfers for the radial-nerve palsy either simultaneously or shortly afterward? Two factors must be clarified before an absolute answer to this problem can be obtained. A good classification of results with radial-nerve injuries has not been presented. Some have called a result good if a patient returned to work. A good result following radial-nerve palsy must have correction of wrist-drop, of flexion deformity of the metacarpophalangeal joints, and of the dropped and flexed thumb. Prolonged splinting causes stiffness in fingers. In view of the fact that there is no universal classification of results with radial-nerve injuries, there can be no uniformity in reports on results. It is generally believed that results following radial-nerve repair are good. However, reports following World War I would indicate that about 25 per cent. were failures. Mark Iselin, of Paris, advises early tendon transfer following radial-nerve repair.

Dr. Leo Mayer [22] suggested a review of the paper by Sir Harry Platt on the subject of results following radial-nerve suture. He covered the results of 500 or 600 cases and found a very high percentage of return of function in the radial nerve. Recovery was best in that nerve.

Dr. Raymond M. Curtis [29] brought up the question whether the incidence of causalgia was greater in those patients who had nerves primarily or secondarily repaired. He had had two patients with median-nerve laceration not repaired primarily in whom a true sympathetic dystrophy of the involved extremity had developed prior to secondary-nerve suture. In looking back on these two cases, he had wondered if the result would have been different if a primary nerve repair had been carried out. It is his opinion that where possible primary repair of the lacerated nerve should be performed.

At the business session held on Saturday, January 23, the following officers were elected for the year 1954–1955:

President-Elect: S. Benjamin Fowler, M.D., Nashville, Tennessee;
Vice-President: Arthur J. Barsky, M.D., New York, N. Y.;
Historian: Julian Bruner, M.D., Des Moines, Iowa;
Secretary-Treasurer: George V. Webster, M.D., Pasadena, California.
The President for the year 1954–1955 is Dr. Joseph H. Boyes.

The next Annual Meeting will be held at the Statler Hotel, Los Angeles, California, Friday, January 28, 1955.

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Twenty-first Annual Meeting of The American Academy of Orthopaedic Surgeons was held at the Palmer House in Chicago, January 23 to 28, 1954, under the presidency of Dr. Harold B. Boyd.

As arranged by Dr. Alvin J. Ingram and his committee, the Scientific Program was excellent. The Scientific Sessions were opened on the afternoon of January 24 and were continued during part of each day through January 28. Summaries of the papers presented at these sessions follow:

Sunday, January 24, 1954

The Pathogenesis of Delayed Union and Non-Union. Dr. Marshall R. Urist [1] and Dr. Robert Mazet, Jr.,[2] studied and compared 100 consecutive fractures of the tibia which had healed without bone-grafting and eighty-five comparable ununited fractures; they attempted to elucidate the basic biochemical and physical derangements in the healing process. Their studies included exhaustive analyses of the patients' records, serial roentgenograms, follow-up examinations, and routine pathological and histochemical studies of biopsy specimens from fractures treated by bone-grafting and from fracture sites in limbs amputated for non-union.

In the control fractures, healing time was proportional to the length of the shaft damaged. Comminution, surgery, internal fixation, and sepsis affected the healing time only in so far as they produced devitalized tissue between the viable bone ends. The shaft of the tibia in the adult was found to regenerate at the rate of one centimeter per year. The authors concluded that the minimum healing time required before bone-grafting is advised should be twelve months for non-comminuted fractures, eighteen months for slightly comminuted fractures, and twenty-four months for severely comminuted or displaced segmental fractures. Furthermore, they expressed the conviction that multiple wedge and segmental fractures were "non-operable", since open reduction had merely increased bone necrosis and had depressed osteogenesis. It was noted that about 15 per cent. of the control fractures showed the characteristics often considered to indicate non-union or delayed union, while 5 per cent. of control fractures closely resembled the ununited fractures seen among the eighty-five cases which had been subjected to bone-grafting. In spite of this appearance, union had occurred simply with prolonged immobilization.

The eighty-five ununited fractures were analyzed with reference to: (1) displacement, comminution, and missing bone substance, (2) surgical dissection of the fracture site, (3) exposed bone, (4) sepsis, and (5) metallic appliances used for internal fixation. The length of the damaged shaft and the amount of the separation of the viable bone ends were always greater in the ununited fractures than in the control fractures.

Two stages in fracture healing were identified: (1) the proliferative phase during the first six months of healing, characterized by the production of new bone from the endosteum and periosteum and (2) the replacement phase in which dead bone and fibrocartilaginous callus were replaced by new bone without visible external change. In incomplete or undisplaced fractures which healed within six months, the replacement phase was hardly apparent and was of no importance. In slow-healing and ununited fractures, on the other hand, the replacement phase was greatly prolonged and was preceded by a latent period of relative inactivity.

Anatomical and histological examinations were made of biopsy specimens from fifty fractures, from nine fractures in limbs amputated because of non-union, and from one fracture which had healed in a tibia obtained at autopsy seven years after injury; eleven biopsy specimens were obtained four to six months after injury. The only tissue found in specimens from fractures with delayed union or non-union, not present in normal fractures, appeared in the middle of the fracture gap and consisted of incompletely organized fracture hematomata, partially liquefied hematomata within a dense fibrous capsule, or even sterile pus in fractures in which infection had not been considered possible. Chronic inflammatory connective tissue and amorphous material consisting of fibrinoid, hyaline, and mucinous fluid appeared in the fracture gap subsequently. The histochemical characteristics of the amorphous material were demonstrated by various techniques. The presence of fibrinoid in the later stages of healing was interpreted as evidence of a defective cartilage model and an inadequate induction system for bridging the fracture gap. An additional finding was the failure of the dense scar tissue normally present in callus to regress and to be changed to bone. This was found especially in cases with chronic sepsis, but it was also found in the presence of purely traumatic inflammation resulting from motion at the site of non-union.

Fifty specimens were examined six to twenty-four months after injury. These showed essentially the same changes; they were, however, more advanced.

Nineteen specimens examined two to five years after injury showed the formation of mature pseudarthroses. The proximal bone end was expanded and saucerized, while the distal bone end was rounded. Opposing bone ends consisted of bone, fibrocartilage, and collagenous fibers, together with a laminated amorphous material which included fibrinoid. About the periphery of the cup-shaped proximal bone end there was evidence of continuous new-bone formation, indicating that the process of bone repair had not ceased, but rather that it was misdirected and was not drawn into the fracture gap to produce union.

[1] 1019 Gayley Avenue, Los Angeles 24, California.
[2] U. S. Veterans Hospital, Los Angeles 25, California.

The results of ten types of surgical operations for ununited fractures were studied. It was concluded that all of the standard surgical procedures for bone-grafting are capable of producing union, but that the success of the operation is determined by the proliferative reaction of the bone ends and not by the bone graft. The operation was thought to introduce a new injury and a new proliferative response. The bone graft did not take an active part, but appeared to act as a catalyst or inductor, being incorporated into the host bed after union had occurred. Bone-grafting without the excision of the fibrocartilaginous callus was found to be successful before eighteen months of healing had elapsed. After this, excision of the bone ends, osteotomy of the fibula, and telescoping of the fracture to produce contact of viable bone ends was deemed advisable. Recurrence of sepsis was the chief cause of failure of all bone-grafting procedures. Radical leg shortening, which had been used successfully in five cases, was offered as an alternative to amputation in old ununited fractures with large, soft-tissue defects after repeated bone-grafting operations.

Dr. Granville A. Bennett [2], in discussing this paper, briefly reviewed the factors which impair fracture healing and emphasized that, although the finding of fibrinoid in the fracture callus was of interest, its significance must be interpreted with caution. Fibrinoid is difficult to define exactly, and its occurrence may represent either the cause or the result of defective healing sequence.

Dr. John J. Flanagan [4] emphasized the importance of distraction and impaired blood supply in the development of delayed union. He made a plea for closed reduction whenever possible and for the early recognition of delayed union. If, after three months, union appears to be delayed, he favored drilling of the bone through the periosteum. Thirty to fifty channels, made in this manner, were advised.

Muscle-Pedicle Bone Grafts. Dr. Joel Hartley [5] and Dr. Norman Silver [6] gave a straightforward report on experiments carried out on rabbits in an attempt to answer the question can autogenous bone grafts be kept viable if a muscle pedicle is permitted to remain attached. Control experiments in which bone grafts were used without muscle pedicles revealed necrosis of the bone grafts. Bone grafts retained viability from one-seventh to nine-tenths of the thickness of the graft in cases in which muscle pedicles had remained attached. In a few instances in which the pedicle had become replaced by scar, there was total bone necrosis. These experiments were of interest because tantalum foil had been placed around the bone in such a way that any viability of bone would necessarily be the result of nutrition fed through the muscle pedicle. The grafts in these experiments were taken from the lateral portion of the ilium, and portions of the gluteal muscles were left attached to act as pedicles.

Dr. Joe B. Davis [7] discussed the muscle-pedicle graft. His and Dr. Taylor's experimental and clinical results were essentially the same as those presented by Dr. Hartley. He had utilized the anterior crest of the ilium with the tensor fasciae latae and the anterior part of the glutaeus medius attached in hip fusion and the posterior crest of the ilium with the glutaeus maximus attached in sacro-iliac arthrodesis. He had not been able to utilize in lumbosacral fusion the posterior crest of the ilium with the sacrospinalis attached, but he had been able to use successfully an acromion-deltoid graft in shoulder arthrodesis.

Dr. Paul R. Lipscomb [8] emphasized the importance of recognizing the age of the animals in all experimental studies of osteogenesis. Comparable results are possible only when animals used are of the same age, size, and strain and of the same environmental influences and, preferably, sex. He also pointed out that frankly necrotic and newly formed and proliferating bone can be distinguished microscopically, yet it often could not be definitely determined whether a given section of mature bone had been alive or dead at the time the animal was sacrificed. Cells of normal appearance occupying lacunae may not have been alive and cells which appeared shriveled in the sections may not have been dead. If there is evidence that an osteocyte reverted to the form and function of an osteoblast and multiplied under the stimulus of injury or disease, it may be accepted that it was alive. He considered that the work of Dr. Hartley and Dr. Silver had shown conclusively that "an isolated segment of bone in a short muscle-pedicle graft" is capable of repair when fractured; further work is necessary before one may conclude that a longer muscle pedicle and one twisted on itself is capable of producing adequate nourishment.

Osteotomy and Osteotomy Combined with Bone-Grafting in the Treatment of Non-Union Following Fracture of the Femoral Neck. Dr. Marcus J. Stewart [9] and Dr. Robert E. Wells [10] referred briefly to the various methods of treatment of fractures of the femoral neck, including reconstruction and the recent increasingly popular hip prosthesis. They presented a critical analysis of 100 cases of non-union in fractures of the femoral neck which had been treated by various types of high and low angulation osteotomy, and they provided a somewhat discouraging picture because of the incidence of arthritis and aseptic necrosis. In an effort to im-

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[7] 815 Standard Insurance Building, Portland 5, Oregon.
[8] 1801 Medical Arts Building, Fort Worth, Texas.
[9] 869 Madison Avenue, Memphis 3, Tennessee.
[10] 869 Madison Avenue, Memphis 3, Tennessee.

prove these results, osteotomy had been combined with the insertion of a bone graft through the osteotomy site and into the femoral head. Twelve additional cases were reported in which this had been done after the method of Phemister. The method is based on the principle of revascularization of the femoral head through the creation of a new channel of blood to the capital portion of the femur from the rich vascular area at the osteotomy site. Internal fixation is provided. Preliminary results suggest the usefulness of this operation in selected cases of non-union in which the femoral head is intact and its circulatory status is questionable.

Function of a normal femoral head was felt to be superior to that of any prosthesis.

Discussing the report, Dr. James A. Dickson [11] stated that his own conclusions regarding failure of union and avascular necrosis were that these complications must be detected early, that the fracture must be converted into a low angle type by osteotomy in order to overcome shearing stresses, and that a bone graft must be inserted in order to provide internal fixation and to stimulate revascularization and creeping substitution. He believes that cancellous grafts for this work are superior to cortical grafts.

Dr. Paul C. Colonna [12], in discussing this paper, took exception to the phrase "increasingly popular hip prosthesis". He detected a much more careful selection of cases for this procedure and an over-all lack of enthusiasm among orthopaedic surgeons for it. He hoped that the hip prosthesis would be more constructively and selectively employed. Dr. Colonna said that he had found it difficult to detect avascular necrosis. Of course patients giving roentgenographic evidence of absorption and frank necrosis and those without evidence of necrosis present no problem; patients in the "in-between" group are those in whom diagnosis of necrosis is difficult. He felt that shortening of the extremity of 2.5 centimeters or more, present in half of the patients, could have been avoided with the use of the Dickson geometric osteotomy or his trochanteric reconstruction.

Popliteal Cysts Associated with Undiagnosed Posterior Lesions of the Medial Meniscus. Dr. Harold M. Childress [13] reported having excised twenty-one popliteal cysts (Baker's cysts) in seven years. There were no recurrences. In three patients, however, the result was unsatisfactory and each was later re-operated upon, at which time arthrotomy revealed a previously undiagnosed tear of the posterior part of the medial meniscus. Excision of the torn meniscus relieved symptoms in each.

Three additional patients were operated upon, and the meniscus only was excised. In two of these, the cyst subsided spontaneously, while in the third it was subsequently removed.

The author feels that a new approach to the treatment of popliteal cysts is indicated. In the preliminary examination, the knee and the cyst should be aspirated, and the knee should be carefully examined for evidence of tear of the meniscus. If such a tear is found, the meniscus, not the cyst, should be excised.

In discussion, Dr. William H. Bickel [14] reported that, in a series of 100 consecutive popliteal cysts removed at the Mayo Clinic, 14 per cent. were associated with rheumatoid arthritis, while 12 per cent. were associated with various other forms of joint disease. A recent case was found which was associated with villonodular synovitis. This had been overlooked elsewhere at the time the cyst had been excised. Two per cent. of the cases were associated with meniscal injuries.

Monday, January 25, 1954

An Evaluation of the Putti-Platt Reconstruction Procedure for Recurrent Shoulder Dislocation. Col. Ernest A. Brav [15] reviewed his experience with sixty-nine patients with recurrent dislocation of the shoulder who had been operated upon according to the original Putti-Platt reconstruction (thirty-one patients) or a modification of that procedure (thirty-eight patients). The modification of the Putti-Platt operation consists in a shorter and straighter incision and the ligation of the cephalic vein. The conjoined tendon is not excised from the coracoid, the glenoid cavity is not curetted anteriorly, and the distal stump of the subscapularis tendon is not sutured to the capsule but is left loose inside the shoulder joint; the capsule and the subscapularis muscle are sutured over it anteriorly. It was pointed out that recurrent dislocation of the shoulder occurred on the subdominant side in twice as many patients as it did on the dominant side; this is seemingly due to the inferior muscle development and coordination on that side. Almost 25 per cent. of the patients gave no history of injury whatsoever prior to the development of recurrent dislocation of the shoulder, and eighty-three per cent. of the patients had had inadequate treatment of the first dislocation. The common changes, as seen roentgenographically, were a defect of the humeral head (seen in forty-one of sixty-five patients), the development of new bone in the anterior lip of the glenoid labrum (seen in twelve of sixty-five patients), and loose bodies in the shoulder (seen in four of sixty-five patients). The most common operative finding in the series was a thinning, with or without separation, of the glenoid labrum anteriorly and inferiorly.

Recurring dislocation occurred in three patients of the sixty-nine; two of these patients had been subjected to the simpler modified procedure. In three other patients, stiffness of the shoulder developed which

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[14] Mayo Clinic, Rochester, Minnesota.
[15] Walter Reed Army Hospital, Washington, D. C.

required manipulation following surgery; three patients in the group were dissatisfied with the result because of pain and limitation of motion to a degree which interfered with their desired activities. All patients with successful results had some degree of external rotation following the procedure. The author advises waiting at least one month after a dislocation before a reconstructive procedure is attempted.

In discussing the report, Dr. Carter R. Rowe [16] pointed out that postoperative recurrence in a series in which the standard Putti-Platt procedure had been used was only 4.5 per cent. for a five-year period, whereas postoperative recurrence in the series treated by the modified operation was 10 per cent. for a two-year period. He questioned the advisability of using the simplified procedure on young active patients. Recognizing that recurrence falls off sharply after forty-five years of age, he felt that there might be some justification for using the shorter and easier operation in older patients. Reviewing other published recurrence rates for various widely used operations, he emphasized that any procedure which results in recurrence in over 5 to 6 per cent. is substandard. He stressed the importance of long follow-up — in one series he had found 33 per cent. recurrence in one to three years, 29 per cent. recurrence in three to five years, and 38 per cent. recurrence in five to ten years.

Dr. Paul B. Magnuson [17] called attention to the one absolute essential in operations for recurrent dislocation of the shoulder, namely, the provision of an active restraint to forward displacement by the forcible holding of the humeral head in the joint. He considered, as recommended in his operation, the subscapularis muscle ideal for this purpose. The divided insertion of the muscle is sutured to the bone at the anterior lip of the bicipital groove below the tip of the greater tuberosity. He stated that he had had no recurrences since he began to use this operation in 1941.

In closing the discussion, Col. Brav regarded a recurrence in two of nineteen patients as not necessarily being 10 per cent. because of the smallness of the series. He stated that he had seen many recurrences after the Bankhart and the Magnuson operations.

The Surgical Management of Residual Deformities of the Shoulder Following Birth Injuries of the Brachial Plexus. Dr. Jack Wickstrom [18], Dr. Edward T. Haslam [19], and Dr. Robert H. Hutchinson [20] presented an encouraging report of the results of their treatment of obstetrical paralysis in fifty-four patients. Damage to the brachial plexus was minimal in twenty-eight patients and was moderate in two patients. Exercises and abduction splinting had yielded lasting satisfactory results. Surgery had been necessary in twenty-four patients; all of these showed moderate or severe nerve injuries. Section of the pectoralis major and of the subscapularis (Sever operation) had been carried out in three. These patients showed improved external rotation without an increase in the range of abduction, but there was a tendency for the improved external rotation to be lost over the years. In ten patients, release of the contracted internal rotators was combined with the transplantation of the insertions of the teres major and the latissimus dorsi, posteriorly and laterally, beneath the lateral head of the biceps (the L'Episcopo operation). Improvement in external rotation and abduction was not only maintained but was continued. When a long-standing internal rotation contracture had resulted in a flattened humeral head and a deformed glenoid fossa which prevented rotation (six patients), derotation osteotomy of the humerus above the insertion of the deltoid had improved function, making it possible for the patient to bring the hand to the mouth in a natural manner. In several patients, there had also ensued improvement in abduction. Five patients had had posterior dislocation of the humeral head with fixed internal-rotation contractures. Release of the subscapularis and the pectoralis, together with an open reduction of the dislocation (Fairbank operation), had given excellent results in four. The operation had been modified by the addition of internal fixation of the humeral head to the glenoid labrum in external rotation by means of a transfixing Steinmann pin which was left in place for four weeks. This was followed by additional immobilization in the corrected position for three more weeks. A striking feature after reduction in the group of patients with dislocation and in those treated with derotation osteotomy was the marked improvement in function of the entire arm.

Discussing the report, Dr. Carl Badgley [21] spoke favoring treatment by shoulder fusion in patients whose shoulder joints had become deformed and were otherwise unsuited to the L'Episcopo operation. He had found the L'Episcopo operation to be a most successful procedure for those patients who can passively raise the arm in external rotation but who cannot actively do so. He felt that in the older patients there was a place for the derotation osteotomy.

Dr. Tom Outland [22] stressed the great importance of evaluating the extremity as a whole before treatment was decided upon.

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[17] 700 North Michigan Avenue, Chicago 11, Illinois.
[18] 1430 Tulane Avenue, New Orleans, Louisiana.
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[20] 1430 Tulane Avenue, New Orleans, Louisiana.
[21] 1313 East Ann Street, Ann Arbor, Michigan.
[22] 412 North Second Street, Harrisburg, Pennsylvania.

The Transmetatarsal Amputation in Peripheral Vascular Disease. Dr. Herbert E. Pedersen [23] and Dr. A. Jackson Day [24] reported a series of twenty-three transmetatarsal amputations, as recommended by Dr. McKittrick in 1944, in twenty-one patients with gangrene of one or more toes due to peripheral vascular disease. Three were for thrombo-angiitis obliterans, five were for arteriosclerosis, and fifteen were for diabetes with arteriosclerosis. Mild to moderate cellulitis was present in all but one instance. Proper selection of cases is essential; the gangrene and infection must be stabilized, and the gangrene must be confined to the toe level. The better the nutritional status of the foot as a whole, the better the chance of success; yet the absence of a palpable pulse below the iliac or femoral arteries is no contra-indication. Patients are told of the advantage of the low level of the amputation, by which they may be free of a prosthesis, but they are warned of the definite possibility of failure. Two to three weeks of recumbency, with the head of the bed elevated a few inches, is essential. During this period of preparation, every accredited means of stabilizing the infection is instituted, and only after the gangrene and infection have become stabilized can the transmetatarsal amputation be considered.

The incision across the dorsum of the foot and the level of the bone amputation are just proximal to the metatarsal heads. A long plantar flap is made by carrying the incision across the sole and down to the bone about one centimeter proximal to the proximal flexion crease of the toes. The most painstaking gentleness is indispensable. A one-layer closure is preferable; this should be exact and smooth.

Of the twenty-three amputations, eight healed by first intention, none healed secondarily, and four were reported to have small areas of granulation and should heal. Two amputations were gross failures, and above-the-knee amputations for progressive gangrene were done. In 56 per cent. of the patients, wound healing was delayed.

In discussion, Dr. Donald B. Slocum [25] re-emphasized the importance of thorough preparation, whereby the gangrene and the infection are first stabilized, before operation may be considered. The operation is contra-indicated when the gangrene is due to sudden arterial occlusion.

Dr. Harry D. Morris [26] felt that the long period of preparation before the amputation could be properly performed often made the procedure difficult to choose for economic reasons.

The Internal Architecture of the Femur. Its Clinical Significance. Dr. William J. Tobin [27] discussed the trabecular pattern and cortical structure of the upper end of the femur. The normal structure of the femur was discussed first; Dr. Tobin then dealt with the effect morphologically of varus and valgus deformities. The effects of function on structure were illustrated by the form of the upper portion of the femur of the sloth. Lastly, the proper position of a nail in order to secure the most effective fixation in the treatment of fracture of the femoral neck was discussed, as well as fundamental considerations in the design and insertion of hip prostheses.

This study was instructively discussed by Dr. Edward T. Haboush [28] from the point of view of the biologist and by Dr. Charles W. Goff [29] from the point of view of the anthropologist.

Vertebra Plana (Calvé's Disease) Due to Eosinophilic Granuloma. In a well documented presentation, Dr. Edward L. Compere [30], Dr. William E. Johnson [31], and Dr. Mark B. Conventry [32] advanced the concept that so-called Calvé's disease was due to eosinophilic granuloma of the vertebral body. In support of their claim, they presented four patients with characteristic vertebral-body changes which had been demonstrated by x-ray. In each the diagnosis of eosinophilic granuloma had been proved by open biopsy; one had a proved rib lesion in addition to vertebral-body involvement, one had a proved lesion of the eighth thoracic vertebra, one had a lesion of the fifth thoracic vertebra, and the fourth had a comparable lesion of the fourth thoracic vertebra, together with lesions of the same appearance in the left clavicle and in the left seventh rib. Resection of a portion of this rib revealed eosinophilic granuloma.

The discussion was opened by Dr. J. William Hillman [33] who reported a case similar to the four shown which had proved on open biopsy to be a highly malignant undifferentiated sarcoma.

Dr. Samuel Prevo [34] expressed the view that neoplastic or hematogenous osteomyelitic lesions might conceivably show a picture similar, clinically and roentgenographically, to that seen in the active phase of disease in the cases presented. When the vertebral body is flattened and sclerotic, as described by Calvé, he suggests that the disease process is spent and the diagnosis would not then be important in treatment.

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[27] 1835 Eye Street, N.W., Washington, D. C.
[28] 1036 Park Avenue, New York 28, N. Y.
[29] 30 Farmington Avenue, Hartford, Connecticut.
[30] 116 South Michigan Avenue, Chicago 3, Illinois.
[31] Mayo Foundation, Rochester, Minnesota.
[32] Mayo Clinic, Rochester, Minnesota.
[33] Vanderbilt University Hospital, Nashville, Tennessee.
[34] 2108 West End Avenue, Nashville, Tennessee.

TUESDAY, JANUARY 26, 1954

The Management of Arterial Injuries in Battle Casualties. DR. FRANK C. SPENCER [35] and DR. RAY V. GREWE [36] reported their experience in treating ninety-seven arterial injuries in eighty-five patients in active military duty in Korea. Surgical repair had been made possible a few hours after injury through helicopter evacuation of the injured. Arterial repair was considered for all injuries to major arteries, the major arteries being the subclavian, axillary, brachial, iliac, femoral, popliteal, and posterior tibial above the peroneal artery. The crucial considerations in each case were the additional time needed for the repair in view of the needs of other wounds, the hazard of infection, and the factor of limb survival in relation to the time between the infliction of the wound and the completion of arterial repair.

The majority of the patients were seen four to six hours after injury; a few were seen fifteen to thirty hours after injury. No primary amputations were done, although it was recognized that, if the preoperative ischaemic changes were irreversible, amputation might be necessary.

Pressure dressings of gauze had usually controlled hemorrhage. Tourniquets were employed infrequently.

Diagnosis offered no problem when the limb was cold, pale, and pulseless. Bright blood usually meant arterial injury. A history of shock at the time of injury and small wounds with no active bleeding often meant arterial injury with a sealing clot. In some cases, no indication of arterial injury was noted before operation.

The intravenous administration of three to five liters of blood under pressure usually allowed completion of preoperative resuscitation in one to three hours.

Spinal anaesthesia or brachial plexus block was used in the less severely injured. A tourniquet was used only until the ends of the injured vessel had been isolated; this saved time. Arterial occlusion was secured with bulldog serrefine clamps or rubber catheters. Only grossly injured arterial segments were removed, although the intima was often more damaged than could be seen externally. Removal of the adventitia from the ends of the arteries facilitated suturing which was done with 00000 silk, the Carrel triangulation technique being used. When narrowing of the vessel did not exceed 20 to 30 per cent., lateral or transverse repairs were done. End-to-end suturing was used when approximation was possible without too great tension. Arterial homografts were used when arterial ends could not be approximated. Extensive mobilization of the artery with ligation of branches was not done. Most of the grafts were four to six centimeters in length. Venous autografts were used in three of the early patients in the series.

After suture, restoration of arterial and venous flow was prompt and strong. Arterial spasm was infrequent; when it was present, it subsided in fifteen to thirty minutes after the topical application of 2 per cent. papaverine. Irrigation was done during the suturing with a dilute heparin solution; otherwise anticoagulants were not used.

The accompanying vein was ligated only if it had been injured. Débridement was complete. The sutured vessel was surrounded by soft parts held in place by sutures. Otherwise, the wound was left open for closure by secondary suture in four to seven days.

Anterior and posterior fasciotomies were done extensively in the lower extremity following popliteal injuries because the muscles of the lower extremity are so prone to ischaemic necrosis.

Following operation, the limb was usually immobilized for three weeks in a posterior plaster molded splint. Adequate blood replacement was felt to be the most important preventative of vasoconstriction. If restoration of the local circulatory status had not been achieved in four to six hours, re-exploration was seriously considered.

Detailed results were available in most cases over a period of four to eight weeks of follow-up. There were six deaths, two of which may have been related to the arterial repair. Twenty cases (22 per cent.) came to amputation; about half of the amputations were attributable to irreversible preoperative ischaemia (in seven of the ten cases, fourteen hours had elapsed between wound infliction and arterial repair). Forty-seven of the cases were repaired with a vascular graft of which forty-four were arterial homografts and three were venous autografts. There were twenty-four anastomoses, eighteen lateral sutures, and eight ligations.

As a result of this experience, it was concluded that vascular repair is a feasible procedure which requires considerable over-all knowledge of vascular surgery.

Presidential Address: Global Orthopaedics. DR. HAROLD B. BOYD. This Address was published in full in *The Journal of Bone and Joint Surgery,* **36-A**: 213–218, April 1954.

A Continuing End-Result Study of Intracapsular Fractures of the Neck of the Femur. DR. MATHER CLEVELAND [37] and DR. J. W. FIELDING [38] demonstrated the value of continuing case analyses in fractures of the femoral neck. Of their last 100 cases, the present study shows that sixty-three with displaced fractures were followed; forty-nine fractures united. Twelve patients showed circulatory changes in the femoral head; this was of a major crippling disability in seven.

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[38] 742 Park Avenue, New York, N. Y.

Resort to open reduction was necessary in three patients because of the inability to reduce the fracture by manipulation. In two of the patients who underwent open reduction, the fracture united without complications; in one it failed to unite.

Eight of the fourteen instances of failure of union were attributed to inadequate initial reduction and six to faulty insertion of the nail.

When avascular necrosis had developed, it usually occurred within eighteen months. In two instances, it was first noted at two years; in another it was first seen at twenty-seven months.

The comparison of results of the present series with 235 patients previously reviewed is of interest.

In the discussion which followed, Dr. Earl D. McBride [39] and Dr. Lenox D. Baker [40] stated that their results were comparable and that they felt that every effort should be made to obtain union and a viable head. For this there is no substitute.

Intermittent Claudication of the Hip. Dr. George S. Phalen [41] called attention to a cause of low-back and sciatic-distribution pain which is not generally recognized and, consequently, often escapes diagnosis. Pain and weakness on limited exertion, with prompt and complete relief with rest, frequently found referred to the calf, may occur in the low back, the buttock, and in the posterior portion of the thigh, leg, and outer border of the foot. It is due to occlusive disease of the terminal aorta or iliac arteries. Evidence was presented that the condition is not uncommon.

In discussion, Dr. Ormand C. Julian [42] pointed out that in the involved regions no notable structural changes occur because collateral circulation develops which is adequate for maintenance provided activities are limited. There is definite evidence of limited blood supply to the extremity, although it is not clear why one patient with iliac obstruction may have hip claudication and another may have calf claudication. He had not found bilateral lumbar sympathectomy to be uniformly successful in the treatment of calf claudication; results from its use in the treatment of hip claudication were not definitely known. Arterial resection with homologous-graft replacement had been successful in seven of nine patients who had hip claudication or calf claudication.

Bone and Joint Tuberculosis and Its Treatment. Dr. Oswaldo P. Campos [43] presented a scholarly treatise on tuberculosis dealing with the development of the primary lesion through the primary complex and the later involvement of osseous and joint structures. The opinions and writings of many men were reviewed. On the basis of his own personal experience, he accepted or ruled out certain opinions, thus enhancing the value of his review. The control of the progress of the lesion by the general measures available before the introduction of antibiotics or chemicals was contrasted with that made possible by the advances in treatment which developed from the use of streptomycin and, later, from the use of the chemical isoniazid. He had not tried iproniazid. He indicated his intention of furthering his study with the use of iproniazid in a controlled series. His experiences indicated that the late reactivation of a tuberculous infection in a joint which had not been solidly ankylosed is always a danger and that ankylosing surgery in weight-bearing joints is still needed. He emphasized the fact that paraplegia requires treatment by spinal ankylosis and that the use of laminectomy in the treatment of this complication is without foundation. He confirmed the findings of others that the sedimentation rate is not a reliable guide. Most important was his reference to the lymphomonocytic index. This he credited with giving positive evidence of the acute invasive stage of bone or joint disease, during which stage one is defeated if one attempts surgery. He noted that this acute invasive stage can be more rapidly terminated by the use of streptomycin than was possible before streptomycin was available; and it is even more rapidly terminated by the use of isoniazid.

Internal Rotation of the Tibia. Dr. William W. Howe [44] and Dr. Louis A. Goldstein [45] discussed the clinical detection of medial tibial rotation, the factors in its development, and the conditions with which it is clinically associated. They felt that the clinically significant expression of tibial rotation is the angle made by the long axis of the foot in "the neutral position" with the long axis of the thigh when the knee is flexed at 90 degrees. The angle is "sight measured".

At birth, medial tibial torsion of 10 to 30 degrees or more was found in 98 per cent. of 700 tibiae; at five years of age, 14 per cent. of 100 tibiae showed medial torsion of over 5 degrees, and at ten years of age 9 per cent. had over 5 degrees. There is greater involvement of the left tibia than of the right.

Medial tibial torsion, with adduction of the fore part of the foot and adduction contracture of the hip, had been found in various combinations in 144 of 350 infants. Of 450 patients examined, ninety-six presented a "pigeon-toe" appearance which was unassociated with other manifestations of medial torsion. Medial

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[44] 35 Chestnut Street, Rochester 4, N. Y.
[45] 35 Chestnut Street, Rochester 4, N. Y.

torsion was present in all cases of bow-leg, and pigeon-toeing in these cases was not unusual. Compensation was usually gained by the use of the hips in external rotation. Bowing of the lower portions of the tibiae may persist and may be very disfiguring. A late development is degenerative arthritis of the knees; this was seen in nineteen late in life. In most cases, degenerative arthritis was more marked in the medial compartment and was greater on the side of greater torsion; in the few cases in which one of the tibiae had not been involved, there was no change on the unaffected side. Compensation for severe torsion had usually been accomplished by eversion and abduction. Early correction would have prevented this.

Flat feet were observed in 147 patients with medial torsion. If the foot was relatively rigid, pigeon-toeing occurred; if the foot was relaxed, there was abduction and eversion.

Torsion of over 20 degrees was considered to be an indication for the use of the Denis Browne splint worn at night and during naps. Conversion is gradual. Bow legs are corrected with derotation. Follow-up on these patients was not long enough to allow adequate support for the data to be presented.

In discussion, Dr. J. Hiram Kite [46] pointed out that, while in some children medial torsion is a congenital deformity, an angulation occurs at the epiphyseal line at each end of the tibia. He stressed the danger of the knee-chest position which some children assume while sleeping. This is the source of bow-leg and pigeon-toeing. He noted that these children often acquire the habit of sitting with their feet folded under them in the pigeon-toed attitude. He felt that, without inversion in internal rotation of the hip, the tibial deformity is congenital; with inversion, the child has the habit of sitting on the legs. In the latter case, correction of the faulty sitting habit is sufficient, but in the former case, double braces are indicated.

Dr. I. William Nachlas [47] pointed out that an outward rotation of the femur commonly accompanied tibial torsion, that the use of the Denis Browne splint was not without adverse strain effects on the hips, knees, and ankles, and that he favored Dr. Kite's manipulation performed by a carefully instructed mother. He had not had to perform derotation osteotomies.

Wednesday, January 27, 1954

Advantages of Knee Disarticulation over Amputations through the Thigh. Col. J. W. Batch [48], Col. A. W. Spittler [49], and Capt. J. G. McFaddin [50] discussed knee disarticulation with a review of twenty-eight cases treated at Walter Reed Army Hospital since 1950. History, indications, and technique were reviewed; a brief statistical summary was presented. The advantages of the broad-based, insensitive, end-bearing stump, with excellent muscle control, were stressed. From the prosthetic viewpoint, the value of the bulbous stump in the control of the prosthesis and the elimination of the pelvic belt was emphasized. Issue was taken with the statement that such stumps were difficult to fit satisfactorily, and several excellent examples of satisfactory prostheses were shown.

Dr. S. Perry Rogers [51], while extolling the excellence of a satisfactory, well fitted knee disarticulation, warned of the difficulties of obtaining a satisfactory artificial limb, urged the fixation of the patella to the femur, and cautioned against using this amputation in patients with diabetes or arteriosclerotic gangrene.

Dr. James E. Bateman [52] re-affirmed his belief, and that of his colleagues, in the end-bearing principle of the stump, both at the knee and the ankle. He had used the Gritti-Stokes amputation at the knee.

Histopathological Alterations of Adrenal and Anterior Pituitary Glands in Patients Treated with Cortisone. Dr. W. A. Bennett [53] called attention to the dangers of the suppression of adrenal cortical and pituitary function in patients treated with cortisone and corticotropin. He cited two instances in which death had occurred in the immediate postoperative period as the result of adrenal insufficiency. To elucidate this problem, he had investigated the adrenal glands of 190 patients who had received cortisone for such diseases as acute leukaemia, disseminated lupus erythematosus, periarteritis nodosa, and rheumatoid arthritis. The glands showed weight loss and depletion of lipid, resulting in pallor and thinning of the cortex and, as seen microscopically, in shrinking of the cortical cells and disappearance of the lipid granules. There was no decrease in the number of these cells or change in their nuclei, nor were there changes in the interstitial cells. In general, if cortisone had been given for less than five days, if the dosage had been less than 450 milligrams, or if therapy had been discontinued more than twenty days before death, there was little evidence of atrophy. However, considerable individual variation was found. The results of a previous study of seventy-seven pituitary glands obtained from patients who had received cortisone, corticotropin, or both, were also summarized. No appreciable change in weight was found, all changes being confined to the basophils, which represent but 8 per cent. of the cells of the gland. The basophils characteristically showed at first loss of granules from their cytoplasm. This was followed by reticulation or vacuolization and, after prolonged hormone therapy, by hyalinization.

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Such changes are similar to those seen in Cushing's syndrome. Dr. Bennett concluded that there are no clinical or morphological means available at present to determine with accuracy (1) the relationship of adrenal atrophy to the dosage or to the duration of treatment or (2) the time necessary for recovery, which may be weeks or months. The atrophy, loss of lipid, and depression of function of the adrenal cortex, which may be induced by cortisone, are a consequence of suppression of pituitary function rather than a direct effect of cortisone on the adrenal cortex. Since both cortisone and corticotropin may produce similar histological changes in the pituitary gland, it should be assumed that the withdrawal of either may produce acute adrenal insufficiency after surgery. This is an infrequent but serious complication.

Surgical Treatment of Spondylolisthesis without Spinal Fusion (Excision of the Loose Lamina with Decompression of the Nerve Roots). Dr. Gerald G. Gill [54], Dr. John G. Manning [55], and Dr. Hugh L. White [56] stated that back pain and pain of sciatic distribution which may occur in spondylolisthesis are due not to instability of the vertebral body but to nerve-root compression and irritation. This may be produced by one of two mechanisms, or by both. One is the rocking of the loose laminal arch on extension of the spine which may produce traction on the first sacral-nerve root and the other, which they reported to be more common, is compression of the fifth lumbar-nerve root by a mass of bone and fibrocartilage in the area of the defect in the pars interarticularis.

Originally they had performed a decompression operation by removing the loose portion of the arch; this was followed by a spine fusion done laterally. In fifteen subsequent patients, however, complete decompression without spine fusion was carried out. In these, decompression consisted not only in the removal of the loose posterior element and, where indicated, a superior facetectomy but also in the removal of the fibrocartilaginous masses which were found to be almost constantly present in the region of the defects at the pars interarticularis. They described these masses as typical pseudarthroses. The follow-up period of their patients was from five weeks to three and a half years.

Not all patients had complete relief; and, in some, early relief was obtained, but, later, return of lesser symptoms occurred. These symptoms were felt to be due to postoperative adhesions, and treatment usually consisted in the epidural injection of fifty to sixty cubic centimeters of procaine and hydrocortone, deep x-ray therapy, and straight-leg-raising manipulation.

Four of the patients operated upon failed to obtain relief after spine fusion; they were relieved after being subjected to adequate decompression and the removal of the fibrocartilaginous mass.

The authors felt that the patients who were operated upon by the simple removal of the loose portion of the neural arch, with superior facetectomy, occasionally recover more rapidly following the operation than do those in whom spine fusion is undertaken. Typical comments on these patients were: "No support is worn"; "They regain full range of back motion"; "No further vertebral-body displacement has occurred"; "No static backache results".

In discussing this concept of the pain mechanism in spondylolisthesis and the surgical treatment presented, Dr. Lee T. Ford [57] reported a series of patients operated upon on Dr. Key's Service during the past year in whom this decompression technique was used. In each they had found the pathological changes described. Two in this series had had disc rupture which required further nerve-root decompression. They had found it unnecessary to give epidural injections of procaine and hydrocortisone or to resort to postoperative manipulations. They had not encountered further slipping, although they had been fearful of it, and had been prepared to advise fusion if it did occur. Dr. Ford felt that these neural-arch defects were of a higher incidence than generally believed and quoted Roche and Rowe as having reported an incidence of over 6 per cent. in 4,000 skeletons examined.

Dr. Luther M. Strayer, Jr., [58] stated that he too believed the fibrocartilaginous masses described as occurring at the defects in the pars interarticularis may cause nerve-root irritation, and he agreed that the anterior longitudinal ligament is strong enough in most cases to prevent further slipping of the displaced vertebral body. He felt that facetectomy was unnecessary and considered that a well performed fusion followed by careful postoperative management was a good method of treatment for all but patients with severe involvement who presented large and unusual defects. He felt that the method advocated by the author "may lay the foundation for a satisfactory way" to treat the severely involved.

In closing, Dr. Gill emphasized that many in his series were patients who had had one to three unsuccessful fusion operations in good clinics and had been badly disabled before the decompression operation was undertaken.

Dr. Maurice B. Roche [59] writes: "Gratefulness is expressed to the authors for their excellent presentation. I would like to take this occasion to voice a plea for proper terminology. There is an increasing tendency to refer to these lesions as 'pedicle' defects.

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"The arch of a vertebra is formed by the two roots (pedicles) and the two laminae and supports seven processes — one spinous, two transverse, and four articular. The region between the body and the superior articular process has been commonly referred to as the root or pedicle, the region between the superior and inferior articular process as the pars interarticularis, and the portion between the superior articular process and the spinous process as the lamina. Defects may occur in the pedicle, either anterior or posterior to the transverse process, in the pars interarticularis, in the lamina, or in the spinous process.

"Bilateral defects through the pedicle and posterior to the transverse process would therefore separate the body of the vertebra and the transverse process *from* that portion of the vertebral arch including the superior articular processes, the partes interarticulares, the inferior articular processes, the laminae, and the spinous process. Bilateral defects through the pars interarticularis create a separation of the body of the vertebra, the roots, the transverse processes, and the superior articular processes *from* the inferior articular processes, the laminae, and the spinous process.

"It is this latter segment, composed of the inferior articular processes, the laminae, and the spinous process, which apparently is proposed for removal in this presentation. For the sake of avoiding a misconception of the site of this lesion which is under consideration for surgical intervention, and also to avoid confusion in the literature, the difference between the locations of these two lesions is remarked. It is also discussed and illustrated in the paper by T. D. Stewart in *The Journal of Bone and Joint Surgery*, **35-A**: 937–950, Oct. 1953."

Studies in Muscle Transplantation. Dr. E. R. Schottstaedt [60], Dr. L. J. Larsen [61], and Dr. F. C. Bost [62] reported several unusual cases in which new types of muscle transplantations had been done. In most instances both the origin and the insertion of the motor muscle was transposed. Seven patients were reported in whom the pectoralis major was transplanted to substitute for a paralyzed biceps. The best result obtained was in a patient who was able to lift a five-pound weight through a full range of motion and to support eight pounds with his elbow flexed at 90 degrees.

Other transplantations included the latissimus dorsi as a substitute for a paralyzed triceps, the pectoralis major as a substitute for paralyzed neck flexors, and the sternocleidomastoid muscle as a substitute for a paralyzed masseter.

A motion picture was shown to illustrate the preoperative condition and postoperative result in several of the patients. The operations are ingenious in conception and will undoubtedly benefit properly selected patients.

Diagnosis of Orthopaedic Disease by Aspiration Biopsy. Dr. Carlos E. Ottolenghi [63] reported his experience with 1,061 aspiration biopsies. The procedure had proved to be a relatively simple one. No special apparatus had been necessary, except for the spine, and there had been no interference with subsequent surgery. No injury to an organ had occurred in the series; there had been no gross hemorrhage, no spread of infection, and no tumor propagation as a result of the biopsy.

The diagnosis had been established in 895 cases (85 per cent.); it had been doubtful in forty-five cases (4 per cent.); and it had been incorrect in 121 (11 per cent.).

A skilled pathologist, trained in the technique, is necessary. He should know the patient clinically, being informed regarding the history, the physical findings, the roentgenographic evidence, and the laboratory data. A smear should be examined from the cytological standpoint, and sections from various parts of the lesion should be studied microscopically. When there is any question, cultures should be made.

A number of cases diagnosed by aspiration biopsy and reconfirmed at operation were reported, including primary and metastatic bone tumor, hematogenous osteomyelitis, granuloma, echinococcus cyst, and fibrous dysplasia. In a series of 204 cases of tuberculosis of the spine, the diagnosis had been established by aspiration in 84 per cent.

The technique, developed to a very high degree, was clearly demonstrated in an excellent motion-picture film.

Hyperplastic Periosteal Osteogenesis in Infancy. Dr. Harry E. Barnett [64] and Dr. Solomon P. Ditkowsky [65] presented a preliminary report of a study of so-called "colic" babies and a large group of normal infants. Many, particularly the irritable or "colic" babies, were found to have greater or lesser degrees of subperiosteal hyperplastic bone proliferation. The roentgenograms were characterized at first by blurring and fuzziness in the subperiosteal region, then by a pencil streak of subperiosteal calcification which became thickened and lamellated, and finally by consolidation of these subperiosteal lines and resolution. The metaphyses, epiphyseal plates, and epiphyseal ossification centers were not involved. These changes were found in the mandible, humerus, femur, and tibia, in particular, and rarely in the scapula, clavicle, and ribs. In the

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same baby, various stages in the development of these changes were encountered in different bones. In patients with symptoms, the onset was between ten and twenty-one days of age and the duration was three to four months. Characteristically, there was irritability and excessive hunger, with more or less swelling of the face or involved extremities, associated with tenderness and occasionally with pseudoparalysis. (One baby had paresis for two months; fifteen showed transitory weakness only.) Some babies had a fever for as long as two weeks. Laboratory studies, including routine blood and urine studies, as well as blood cultures, agglutination tests, and determinations of ascorbic-acid levels, calcium levels, phosphorus levels, and alkaline-phosphatase levels were all normal. The Kahn test was negative. In six instances, the sedimentation rate was elevated. Biopsy specimens were obtained in six cases, and control pathological studies were carried out on five stillborn infants and five babies who had died under four months of age without signs and symptoms of hyperplastic periosteal osteogenesis. These biopsy specimens showed marked osteoblastic activity, proliferation of the periosteal connective tissue, and slight round-cell infiltration in the overlying muscles. There was no evidence of inflammation or hemorrhage. The ten autopsy specimens used as controls showed similar but less marked changes. Five brief case reports were given of patients presenting this syndrome. The authors concluded that, during the first three to four months of life, a variable degree of subperiosteal bone proliferation occurs in the bones of all infants, while definite hyperplastic reactions occur in association with indurated swellings and tenderness of the face and extremities and hyperirritability in a significant percentage of infants. In addition, a small percentage present the marked x-ray changes and clinical symptoms typical of infantile cortical hyperosteosis. There is no absolute line of demarcation between the changes seen in normal babies and those seen in babies with mild to moderate symptoms.

Dr. J. Vernon Luck [66] in discussing this paper stressed that, because of the rapid growth of the metaphysis and the diaphysis postnatally, subperiosteal proliferation is normal at this age. Furthermore, he pointed out that periosteum can react only by producing new fibrous bone regardless of the specific etiology. He stated that there was no evidence of inflammation in the authors' slides of biopsy specimens and that the changes noted were an exaggeration of the normal growth process which should not be overdiagnosed or overtreated. The appearance was thought to suggest a periosteal response based upon a systemic reaction to a toxic or metabolic alteration such as that caused by a systemic infection.

Dr. Frederick N. Silverman [67], because of the large numbers of cases reported by the authors, suggested in his discussion that either this represented an epidemic of infantile hyperosteosis or else that all babies with hyperosteotic lesions do not have infantile cortical hyperosteosis. He pointed out that unrecognized trauma might be an etiological factor in some of the cases reported. He noted that infantile cortical hyperosteosis shows a familiar tendency and has even been reported as occurring prenatally in two successive pregnancies of one mother, the diagnosis being established by roentgenogram.

Thursday, January 28, 1954

Reconstruction Surgery of the Hand in Cerebral Palsy and Spastic Paralysis Resulting from Spinal-Cord Trauma. Dr. J. Leonard Goldner [68] reported that, of a group of 800 patients with cerebral palsy, 300 patients were found eligible for some type of reconstructive surgery and that, of these, only twelve patients were judged suitable for some type of reconstructive hand surgery. An additional five patients with spastic paralysis resulting from spinal-cord trauma were deemed suitable.

The common deformities encountered were those of flexion of the thumb or of the fingers, so that they were held fixed across or against the palm, those of flexion of the wrist, and those of instability of the finger joints.

The goal of surgical procedures was to release the finger or wrist from the flexed position and to restore the functions of grasp and pinch. Tendon transfers were done when necessary in order to add power to the finger extensors or to the finger flexors. Occasionally, too much power was obtained by tendon transfers. That such soft-part surgery is not too satisfactory is suggested by the need for further surgery to undo overcorrections.

In some cases fusion of the wrist in ulnar deviation served to place the thumb in abduction to the rest of the hand. Wrist fusion, fusion of the metacarpophalangeal joint of the thumb, and interphalangeal arthrodesis were useful procedures.

In cerebral palsy, if a wrist fusion is indicated, the wrist should be fused in a position in which the fingers function best, either straight or in slight volar flexion. In a few cases in which some wrist motion was desirable, the radius was fused to the proximal carpal row only.

The conclusion was drawn that in cerebral palsy "the majority of deformities about the hand cannot be aided by surgery".

Experiences with the Palmer Open Reduction of Os Calcis Fractures. Dr. Jack E. Maxfield [69] and Dr.

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[68] Duke Hospital, Durham, North Carolina.
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F. J. McDermott [70] presented a group of selected cases of fracture of the calcaneus, treated by open reduction, in which the important injury was depression of all or part of the posterior articular surface of the bone. This surface should probably be described as not having been comminuted. In only one case was the articular facet broken into more than two pieces. Under such circumstances, a rather uniform elevation was possible, and the cavity beneath was filled with cancellous-bone grafts.

The cases in which there was comminution or other involvement of the calcaneocuboid joint were not as satisfactory or as responsive to surgery because of the severity of the injury.

The statistical survey of the series of nineteen cases followed for an average of 21.7 months showed that satisfactory results were achieved in about 95 per cent., a third of these being excellent, a third being very good, and the remainder being fair. Dr. Maxfield made it clear that in order that this procedure offer a good prognosis, one should carefully select cases and perform operative correction early. The limitations are obviously established by the type of injury, and the excellent and very good results obtained are limited to the group described.

The Treatment of Fractures of the Os Calcis Involving the Subtalar Joint. A Preliminary Report. Dr. Leonard Barnard [71] and Dr. John K. Odegard [72] proposed a plan of treatment of fractures of the calcaneus which depends basically upon placing the foot in equinus (and slight valgus) in a circular cast with a walking heel. The heel is protected by sponge-rubber padding about half an inch in thickness. No effort is made for surgical restoration nor is treatment by any other measures carried out.

The placing of the walking heel is done in order to prevent any weight-bearing or compression stress on the subtalar joint. At the same time, with the foot in equinus, there is relaxation of the pull on the calcaneus by the heel cord. Early walking with crutches is permitted; the cast is removed at an early period.

The procedure which the author recommends in conjunction with this treatment is basically the preservation of soft-tissue function, particularly that of the peroneal and other tendons in the calcaneal area.

The results are estimated on a functional basis rather than on any anatomical reduction; the method of treatment is applicable to any calcaneal fracture regardless of its severity. The results in a series of twenty cases, followed over a three-year period, were presented; there was minimum pain and the patients were away from work an average of twelve weeks.

It is obvious that this treatment is quite opposite to the Palmer method as presented by Dr. Jack E. Maxfield. Final judgment as to which of these divergent methods of treatment is the more efficient will require a study of a long series of cases treated by operative reduction and by the non-operative reduction techniques.

In discussing the preceeding two papers, Dr. Robert L. Patterson [73] stressed the importance of using a Steinmann pin or Kirschner wire through the posterior fragment in order to aid in the proper restoration of the subtalar joint and the importance of using bone grafts from some region other than the calcaneus itself to fill the space created by the elevation of the depressed fragment. He felt that the results achieved by Dr. Maxfield were especially gratifying in view of the high proportion of patients belonging in the Workmen's Compensation category.

Noting that none of the patients had normal subtalar motion after the operation and that over 30 per cent. of these had no symptoms referable to limitation of motion, Dr. Patterson wondered if later some of these ratings would have to be changed because of the development of degenerative arthritic changes.

In discussing the paper by Dr. Barnard and Dr. Odegard, he reminded the meeting that the conservative management of this fracture is not new. He was in full accord with the view that the soft-parts injury is very important. In support of this he called attention to the general experience that triple arthrodesis, as either a primary or late treatment, is far from being invariably successful. He pleaded for treatment of injuries of the subtalar joint by either anatomical replacement or the elimination of motion.

The Recognition and Treatment of Anteversion in Congenital Dislocation of the Hip. Dr. George Chutnard [74] reported his large experience in the management of congenital dislocation of the hip and presented a method of treatment developed since 1942. He compared a series of 100 cases (eighteen months to eight years of age) with a similar series of 118 cases treated prior to 1942.

The new routine included the use of a roentgenographic-comparison method of estimating the degree of anteversion, the use of skeletal traction followed by reduction, and the use of a special walking-peg cast. Subtrochanteric osteotomies were indicated and were carried out if the angle of anteversion exceeded 45 degrees in the younger patients and 30 degrees in the older patients (that is, those over two years of age).

The result was rated *good* if there was no clinical impairment and if reduction was maintained. In patients involved unilaterally who had been treated by osteotomy, the results were good in 82 per cent.; in those treated without osteotomy, the results were good in 77 per cent. In patients involved bilaterally who had

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been treated by osteotomy, the results were good in 44 per cent.; in those treated without osteotomy, the results were good in 39.5 per cent.

Of those patients involved unilaterally who were treated by osteotomy, 15 per cent. required open reduction, while of those who were not treated by osteotomy, 18 per cent. required open reduction. Comparable figures for the group of patients involved bilaterally were 35 per cent. and 50 per cent.

When all patients were grouped, it was seen that open reduction was necessary in 17 per cent. before 1942 and in 11 per cent. after 1942. Aseptic necrosis occurred in 29 per cent. in the latter group of patients.

Dr. Chuinard concluded that the surest guarantee of a good result lies in the proper relative evaluation of all the dysplastic factors and the sum of all the corrective means used in their proper time. Of these the correction of anteversion is one of the most important.

In discussion, Dr. A. R. Shands, Jr.[75], stated that he considered the author's statistical evidence relating to open reduction as opposed to manipulative reduction and osteotomy as opposed to no osteotomy to be based on too few observations, although he felt the results in the two series did favor derotation osteotomy when indicated by excessive anteversion. The arbitrary values for determining when to perform the osteotomy (45 degrees in patients under two years of age and 30 degrees in those over two years of age) he felt to be dependable, but he considered a more accurate method of measuring anteversion should be employed because faults in the technique of measuring may result in variations of as much as 20 degrees in the values for excessive anteversion. These may now be avoided through the use of the recently described precision methods of measuring. He felt that it was a good idea to postpone osteotomy for the correction of excessive anteversion until the patient has walked in a special cast for six months. During this period of weight-bearing, the joint may respond to the stimulus of weight-bearing by becoming more normal in structure and in stability; thus improved results accrue.

Shortcomings of the Stapling Operation. Dr. Alvia Brockway [76], Dr. William Craig [77], and Dr. B. R. Cockrell [78] presented an interesting summary of four years' experience with epiphyseal stapling. The problem had been approached with caution based on the lack of information available to answer certain questions. Would stapling effectively retard growth? Would staples left in place for two years improve discrepancies in limb lengths sufficiently to make the procedure worth while?

A total of fifty epiphyses were stapled in patients from eight months to ten years of age, and the staples remained in place on the average from two years and twelve days, the longest being four years. In only one patient were the limbs of equal length when the staples were removed. The average follow-up time after removal of the staples was 13.2 months.

The net gain in equalizing limb-length discrepancy was disappointing, but it is of interest that with staples removed the limbs grew again at an equal rate, except in patients in whom complications occurred.

There were ten instances of buried staples, varying degrees of extrusion of staples, and six instances of epiphyseal arrest.

Seven patients had been stapled for knock-knee deformity; most were definitely improved. The authors conceded that epiphyseal stapling poses certain problems, the answers to which can be resolved only by time and further experience.

In discussing the report, Dr. Walter P. Blount [79] and Dr. Charles H. Frantz [80] pointed out that the complications and failures which had occurred in the use of the stapling arrest were due essentially to errors in a technique which is very exacting. The errors in technique which produce these complications and how they may be avoided must be clearly apprehended.

SCIENTIFIC EXHIBITS

Autogenous Epiphyseal Transplant. Dr. Joseph S. Barr [1] presented a well planned and executed exhibition of a striking case study. The distal ulnar epiphysis had been transplanted to the mid-shaft of a congenitally short radius. There was evidence that the transplant remained viable and that growth of two centimeters had occurred. This growth had actually caused dislocation of the radial head.

Oblique Films of the Cervical Spine in Flexion and Extension. Dr. Bedford F. Boylston [2] showed a special roentgenographic technique which is of value in demonstrating subluxation and fracture-dislocation of the facet joints of the cervical spine; these are not visualized by standard techniques. The roentgenographic and confirmatory operative findings in three cases were presented.

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[80] 1810 Wealthy Street, S.E., Grand Rapids 6, Michigan.

[1] 234 Marlborough Street, Boston 16, Massachusetts.
[2] Baylor University College of Medicine, Houston, Texas.

Research in Plastics. Dr. M. C. Corey [3] presented a demonstration of Melmac in roller bandages and the results of experiments in which various plastics had been injected into the bodies of animals. Some interesting work on the toxicity and physical characteristics of plastics was presented. This should be the basis of more experimental work.

Committee on Pathology. As in the past, instructive cases were presented in such a way as to test the observer's diagnostic acumen.

Central Office of The American Academy of Orthopaedic Surgeons.

Surgical Management of Sacral Chordomata and Allied Tumors. Dr. Mark B. Coventry [4], Dr. C. S. MacCarty [5], Dr. J. M. Waugh [6], and Dr. D. C. Dahlin [7] presented a magnificent exhibit showing the surgical treatment of an interesting series of patients with sacral tumors. The presentation of material was made exceptionally effective by the use of moulages to depict the gross appearance, of excellent colored photomicrographs, and of well planned, concise, descriptive charts. A combined surgical approach for the total removal of chordomata was presented together with a demonstration of a method of resection of the sacrum after exposure of the tumor. The second sacral nerve was left intact. This demonstrated for the first time a method of surgical treatment of these tumors in which the entire tumor could be removed and a cure effected. It was also interesting that, as long as the second sacral nerve was left intact, bladder function was not disturbed.

Congenital Dysplasia and Dislocation of the Hip. Dr. William Craig [8], Dr. Donald Norquist [9], Dr. Clark Lauder [10], and Dr. Joseph Risser [11] demonstrated their views on the management of congenital dysplasia and dislocation of the hip. Listed were the diagnostic signs, the usual roentgenographic findings, and methods of treatment in abduction. They also showed by roentgenograms the downward excursion of the femoral head when the hips were in flexion and the knees in complete extension. In addition, there was demonstrated a method of applying traction to both limbs at the same time in a position of marked abduction. The cases shown were mostly in younger children.

Radio-Active Iodine Tracer Studies in Legg-Perthes Disease. Dr. R. W. Emerick [12], Dr. K. E. Corrigan [13], Dr. L. E. Holly [14], and Dr. A. H. Joistad [15] presented four cases in which thyroid dysfunction as confirmed by radio-active iodine uptake studies was found to be associated with coxa plana. Appropriate thyroid therapy seemed to hasten recovery in these cases.

Mechanism of Nerve-Root Compression by the Posterior Elements in Spondylolisthesis and in Spina Bifida Occulta of the First Sacral Segment. Dr. Gerald G. Gill [16] and Dr. Hugh L. White [17] presented an expanded showing of their last years' exhibit. A new approach was demonstrated for the treatment of spondylolisthesis by radical decompression and excision of the posterior elements without spine fusion. The majority of the patients for whom follow-up data was available had some residual back pain; some had radiation of the pain into the extremities. This is a very interesting problem which deserves further work with end-result comparisons of patients treated in this manner with a similar group of patients treated by spine fusion.

Aorta-Iliac Occlusion as a Cause of Back Pain. Dr. A. W. Humphries [18] and Dr. James A. Dickson [19] exhibited several cases of obscure back pain resulting from aorta-iliac occlusion by means of brief case reports and reproductions of aortograms. The syndrome was referred to as intermittent claudication of the hip. The exhibit was of great interest, since few orthopaedic surgeons are familiar with this entity.

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[13] Muskegon, Michigan.
[14] 878 Second Street, Muskegon, Michigan.
[15] 878 Second Street, Muskegon, Michigan.
[16] 655 Sutter Street, San Francisco, California.
[17] 655 Sutter Street, San Francisco, California.
[18] 2020 East 93rd Street, Cleveland 6, Ohio.
[19] 2020 East 93rd Street, Cleveland 6, Ohio.

The Uses of the Universal Flange Nail. Dr. Eugene L. Jewett [20] and Dr. F. DeWitt Stanford [21]. This exhibit was a sequel to the one produced by Dr. Jewett and Dr. Stanford at the meeting one year ago. It presented in considerable detail the authors' experience with the universal flange nail in the fixation of fractures about the hip, in the reconstruction of the hip after fractures complicated by non-union and aseptic necrosis, and in the fixation of femoral supracondylar fractures.

Rehabilitation of Spinal-Cord Injuries. The Liberty Mutual Insurance Company (W. Scott Allan) presented by means of case studies the principles of treatment and rehabilitation of patients who have sustained spinal-cord injuries.

Complications and Errors in Technique of Medullary Nailing of All Long Bones. Dr. J. Otto Lottes [22] and Dr. J. Albert Key [23]. This was an informative and well presented exhibit showing the technical errors and complications encountered by Dr. Lottes and Dr. Key in the treatment of fractures of the femur and tibia by medullary nailing.

Hip-Joint Prosthesis. Dr. Earl D. McBride [24] demonstrated a new approach to the insertion of hip prostheses; a separate screw sleeve is inserted into the stump of the neck and just through the lateral cortex of the femur. It seems that this sleeve can be solidly implanted. After it is in place, a prosthetic head is inserted in such a manner that the stem of the head fits into the sleeve. In this way motion is allowed between the sleeve and the stem; this Dr. McBride feels will resist shock and will relieve stress and strain on the stem of the prosthesis. A number of ingenious devices for the placement of these prostheses were displayed, and a patient was present for demonstration, eight months after the operation. The patient had very little discomfort and walked well with a glutaeus medius limp. Dr. McBride also demonstrated a modified incision which he called an anterolateral incision.

Neuropathic Foot. Dr. Donald S. Miller [25] and Dr. William Lichtman [26] exhibited the various conditions which are the cause of neuropathic changes in the foot by means of photographs and x-rays demonstrating the pathological changes encountered. Among the conditions listed were diabetes, tabes, alcoholism, myelodysplasia, and leprosy. The authors felt that the neuropathic foot resulted from analgesia of the joint and activity.

Sciatic-Nerve and Femoral-Nerve Block in Orthopaedic Surgery. Dr. Daniel C. Moore [27] and Dr. James W. Miller [28]. This was a well illustrated exhibit of the site and technique of injection with the use of local block anaesthesia in the extremities. Methods and materials in use were demonstrated, and the results in 805 cases were given.

Surgical Exposures for the Upper and Lower Extremities. Dr. H. F. Moseley [29] and Helen T. MacArthur [30] displayed a large number of beautifully clear anatomical drawings of surgical exposures in the upper and lower extremities. The standard approaches to the various joints were shown. Booklets with reproductions of these drawings were distributed.

Practical Method of Bone Measurement. Dr. Harry W. O'Dell [31] and Dr. Paul L. Weygandt [32] demonstrated a method of measuring bone length by direct x-ray in which a marked grid is used. When the fixed distance between the two and the plate has been determined, the bone length can be measured clearly on the x-ray plate, as the amount of distortion is felt to be equal at both the grid level and the bone level.

Thoracic Spine Fractures Occurring during Electro-Convulsive Therapy. Dr. Robert B. Portis [33] and Dr. John P. Viboch [34] presented an interesting study of the occurrence of spine fractures resulting from electric-shock therapy. It was shown that 18 per cent. of the patients receiving electric-shock therapy without the administration of drugs received compression fractures, while only 12.5 per cent. of the patients who were

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[32] 640 W. Market Street, Akron, Ohio.
[33] 450 North Bedford Street, Beverly Hills, California.
[34] Veterans Administration Center, Los Angeles, California.

given syncurvine in conjunction with electric-shock therapy suffered compression fractures. They also demonstrated methods of restraining patients in order to avoid fracture, but these had not been effective. They did feel that the use of curare-like drugs reduces the incidence of fractures. Patients in whom fractures occurred as a result of electric-shock treatment were not given any special therapy in regard to the fracture. The authors felt, however, that there were no sequelae as a result of this lack of treatment.

Primary Tumors of the Soft Tissues of the Extremities. Dr. E. H. Soule [35], Dr. M. B. Dockerty [36], Dr. R. K. Ghormley [37], and Members of the Staff [38] summarized in a truly magnificent exhibit the vast experience of the Mayo Clinic with primary tumors of the soft tissues of the extremities. Moulages were used to demonstrate the gross appearance of the tumor and colored transparencies were shown to reveal the histological characteristics of the tumors. Fibromatous tumors comprised 12 per cent. of soft-tissue tumors, and 67 per cent. of these were malignant. Lipomatous tumors comprised 35 per cent. of soft-tissue tumors and 32 per cent. of these were malignant. Angiomatous tumors made up 13 per cent., and 5 per cent. of these were malignant. Neuromatous tumors comprised 19 per cent. of the tumors, and 4 per cent. of these were malignant. Myomatous tumors made up 30 per cent. of soft-tissue tumors and 38 per cent. of these were malignant. Of the miscellaneous tumors, a group representing 20 per cent. of the total, 16 per cent. were malignant. Listed under the heading of miscellaneous tumors were tumors of synovial origin which comprised 46 per cent. of this class; 48 per cent. were listed as fibro-xanthomata and 6 per cent. were unclassified. This excellent study re-emphasized the importance of an accurate diagnosis before surgical removal is planned. This exhibit merited long and careful study.

The Knee Disarticulation. Col. August W. Spittler [39], Col. Joseph W. Batch [40], and Capt. James G. McFaddin [41] showed illustrations of the surgical technique recommended for the knee-disarticulation amputation and roentgenograms of the stumps. The fabrication of the prosthesis and the prosthesis itself fitted to a model were illustrated.

The Evolution and Present Concept of Modern Shoe Design: Examples of Shoes of Various Periods; Dynamic Demands of a Shoe; A New Concept. Dr. H. C. Stein [42] and Dr. I. E. Fixel [43]. In this large and well presented exhibit, the evolution of footwear from the distant past to the present was illustrated, as well as the exhibitors' concept of the dynamics of the foot and of proper shoe design.

Acrylic Replacement Prostheses for Joints of the Upper and Lower Extremities. Dr. Dana M. Street [44]. Various types of prostheses were demonstrated. This exhibit was well presented and was carefully thought out.

Growth in Transplanted Bone. Dr. Charles F. Thompson [45] and Dr. Edward Schaffer [46] presented experimental and clinical data, with roentgenograms, to show that growth will occur in transplanted autogenous epiphyseal plates but not in homogenous transplants. In the illustrations of the clinical experiments, it was difficult to evaluate the amount of growth in some instances, since adequate bone markers had not been used.

Rehabilitation in Poliomyelitis. Dr. Hart E. Van Riper [47]. As in the past, this exhibit offered much valuable information concerning poliomyelitis.

Experimental Production of Pigmented Villonodular Synovitis. Dr. J. M. Young [48] and Dr. Andrew G. Hudacek [49]. This was an interesting study concisely and simply presented. By repeated intra-articular injections of blood over prolonged periods of time, synovial changes which grossly and microscopically resembled villonodular synovitis had been produced.

[35] Mayo Clinic, Rochester, Minnesota.
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[46] 1481 West 10th Street, Indianapolis, Indiana.
[47] National Foundation for Infantile Paralysis, New York, N. Y.
[48] Kennedy Veterans Hospital, Memphis, Tennessee.
[49] Kennedy Veterans Hospital, Memphis, Tennessee.

AUDIO-VISUAL PROGRAM

SATURDAY, JANUARY 23, 1954

Surgical Approaches to the Ankle. Veterans Administration Medical Department, under the direction of Dr. LeRoy Abbott, San Francisco, California.

Surgical Rehabilitation of the Hand. Dr. C. E. Irwin, Warm Springs, Georgia.

Prosthesis for Restoration of Contact Surface of the Patella. Dr. Duncan C. McKeever, Houston, Texas.

Patellectomy. Dr. Paul E. McMaster, Beverly Hills, California.

A New Procedure for Repair of the Collateral Ligaments of the Knee. Dr. J. R. Black, Los Angeles, California.

The Dislocating Elbow. Dr. A. J. Leandi, Springfield, Massachusetts.

Regional Block. Dr. Daniel C. Moore and Dr. James W. Miller, Seattle, Washington.

SUNDAY, JANUARY 24, 1954

Supplementary Fixation in Medullary Nailing of the Femur. Veterans Administration Medical Department, under the direction of Dr. Dana M. Street, Memphis, Tennessee.

Resection of the Upper Half of the Femur with Vitallium Prosthetic Replacement. Veterans Administration Medical Department, under the direction of Dr. Andrew Schildhaus, Brooklyn, New York.

Lumbosacral Spinal Fusion with Metallic Plate Fixation. Dr. Philip D. Wilson and Dr. Lee Ramsay Straub, New York, N. Y.

TUESDAY, JANUARY 26, 1954

Posterior Approach of the Hip Joint and Insertion of a Naden Rieth Prosthesis. Veterans Administration Medical Department, under the direction of Dr. Virgil R. May, Richmond, Virginia.

Teres Major and Latissimus Dorsi Transfer. Dr. Carmelo C. Vitale, Brooklyn, New York.

Avulsion of the Insertion of the Biceps Brachii Tendon. A Method of Surgical Repair. Dr. I. S. McReynolds and Dr. B. D. Burdeaux, Jr., Houston, Texas.

WEDNESDAY, JANUARY 27, 1954

Fractures of the Humerus. Veterans Administration Medical Department, under the direction of Dr. William A. Larmon, Chicago, Illinois.

Hemipelvectomy. Dr. Herbert C. Fett, Brooklyn, New York.

GADGETS EXHIBIT

Thigh-Piece Extension for Lower Leg Cast. Dr. Louis W. Breck, Dr. W. Compere Basom, and Dr. Morton H. Leonard, El Paso, Texas.

Antirotation Brace. Dr. John W. Chenault, Tuskegee Institute, Alabama.

Intramedullary-Bar Cap. Dr. Martin Dobelle, Pittsfield, Massachusetts.

Extension Traction Using Perforated Foam-Rubber Strips. Dr. Maurice Gershman, Far Rockaway, New York.

Knee Meniscus Knife. Dr. M. Beckett Howorth, Stamford, Connecticut.

Hogan Self-Adherent Sponge Rubber Traction Strips and Adjustable Plastic Spreader. Dr. Robert Mazet, Jr., Los Angeles, California.

Plate-Bending Pliers. Dr. Duncan C. McKeever, Houston, Texas.

The Perforated Cruciate Intramedullary Nail. Dr. Michael T. Modny, Glen Ridge, New Jersey.

Universal Traction Device for Home Use. Dr. Howard B. Shorbe, Oklahoma City, Oklahoma.

Cut-off for Applied Steel or Vitallium. Dr. Fred Stuttle, Peoria, Illinois.

Channel Strip for Easy Opening of Plaster Casts. Dr. Edmond Uhry, Jr., New York, N. Y.

The Traction Brace: A New Traction Method in the Conservative Treatment of Intervertebral-Disc Lesions. Dr. Luben S. Walchef, Cincinnati, Ohio.

News Notes

The American Academy of Orthopaedic Surgeons will hold its Twenty-second Annual Meeting at the Hotel Statler, Los Angeles, California, January 29 to February 3, 1955.

A year's fellowship, dates to be arranged, is available in the laboratory of bone and joint pathology of the Ochsner Foundation Hospital. For information write to Mary S. Sherman, M.D., Ochsner Clinic, 3503 Prytania Street, New Orleans 15, Louisiana.

Surgeons are cordially invited to attend the Sixth Congress of the **Pan-Pacific Surgical Association** to be held in Honolulu, October 7–8, 1954. Further information may be obtained from F. J. Pinkerton, M.D., Director General, Pan-Pacific Surgical Association, Young Building, Honolulu, Hawaii.

The 1954 Annual Convention of the **Association of Military Surgeons** will be held at the Hotel Statler, Washington, D. C., from November 28 to December 1, 1954. The Executive Secretary is Stuart E. Womeldorph, Armed Forces Institute of Pathology, Washington 25, D. C.

The Mid-Central States Orthopaedic Society held its First General Meeting at the University of Kansas Continuation Center and the Student Union Building at the University of Kansas Medical Center, Kansas City, Kansas, April 9 and 10, 1954.

The Society is composed of orthopaedic surgeons from Kansas, Missouri, Nebraska, Oklahoma, Colorado, and Arkansas. Present membership is 125 surgeons, seventy-seven of whom attended the meeting.

The First General Meeting was entirely clinical in nature and was presented by members of the Society living in the Greater Kansas City area.

During the morning and afternoon of April 9 and the morning of April 10 cases were presented by Dr. Charles Vilmer, Dr. Robert M. Drisko, Dr. Paul W. Meyer, Dr. Richard H. Kiene, Dr. Otis James, Dr. Nicholas Pickard, Dr. Rex L. Diveley, Dr. Robert Fitzgerald, Dr. Herbert Hamel, Dr. Garret Pipkin, and Dr. Raymond A. McCanse, all of Kansas City, Missouri, and by Dr. Ivan W. Cain, Dr. James B. Weaver, Dr. C. L. Francisco, Dr. L. D. Litton, and Dr. W. D. Francisco, of Kansas City, Kansas.

The following men were elected to office at this meeting:

President: Dr. Vilray Blair, St. Louis, Missouri;
Vice-President: Dr. Elias Margo, Oklahoma City, Oklahoma;
Secretary-Treasurer: Dr. H. O. Anderson, Wichita, Kansas.

LETTER TO THE EDITOR

Redistribution of Bone Salt

To the Editor:

The conclusions reached by Göran C. H. Bauer in his two articles on The Importance of Bone Growth as a Factor in the Redistribution of Bone Salt, published in the April issue of *The Journal of Bone and Joint Surgery* [1,2], do not follow from the experimental evidence presented.

The author recognizes the inescapable fact that the skeleton is a heterogeneous system and that bone formation, resorption, growth, and metabolism vary from one part of the skeleton to another. Not only does trabecular bone differ from cortical bone in this regard, but metaphyseal bone itself has different patterns of growth and metabolism in each separate site of endochondral ossification. A second inescapable fact, which the author fails to note, is that the circulation, and hence the surface area exposed to tissue fluids, is different in the various areas of the skeleton, and diffusion of tissue fluids through the calcified matrix of bone is slow, if it occurs at all. Any equilibrium reached between ions in the blood and the inorganic component of the skeleton depends not only, as stated by the author, on the level of the ion in the blood stream, but also, among other factors, on (1) the chemical state of the ion (that is, bound with protein or in colloidal combination with carbonate, phosphate, or citrate), (2) the rate of flow of the blood, (3) the pH of the blood stream, (4) the

[1] Bauer, G. C. H.: The Importance of Bone Growth as a Factor in the Redistribution of Bone Salt. I. Redistribution of Radio-Active Calcium in the Skeleton of Rats. J. Bone and Joint Surg., **36-A**: 375–380, Apr. 1954.

[2] Bauer, G. C. H.: The Importance of Bone Growth as a Factor in the Redistribution of Bone Salt. II. Redistribution of Radio-Active Phosphorus in the Skeleton of Rats. J. Bone and Joint Surg., **36-A**: 381–386, Apr. 1954.

surface area exposed to the circulating fluids, and (5) the state of "saturation" of the organic matrix (that is, the rate of deposition of new bone). It is difficult to control these factors in an experiment and, indeed, to draw sound conclusions when all are involved and interacting. (Witness the state of confusion concerning the role of the kidney in calcium excretion.)

One of the conclusions reached by the author is that "Parts of the skeleton which differ in rate of growth can . . . never reach equilibrium with respect to the distribution of radio-active phosphorus or radio-active calcium after administration of these isotopes." The basic problem of "equilibrium" is a semantic one. The word is used by Bauer to imply a static situation, or a "steady state". In a growing system this concept is untenable since growth implies change. The word "equilibrium" can also be used in the sense of a "steady rate". In this sense, time becomes a factor in the equation, and the situation can be expressed mathematically *for the skeleton as a whole*, as follows:

$$Qs = \frac{\lambda s Q}{(\lambda e + \lambda s - \lambda m)} \left(e^{-\lambda m t} - e^{(\lambda e + \lambda s)t} \right)$$

Where Qs is the amount of a particular element present in the skeleton at time (t), Q the amount injected, λe the rate of fecal and urinary excretion, λs the rate of skeletal uptake, and λm the rate of mobilization from the skeleton. Equilibrium constants can be developed as above for the skeleton as a whole or for specific portions of the skeleton, provided the time constants are specified.

Another conclusion reached by the author is that "redistribution of bone salt in different parts of the skeleton varies with the rate of growth of these parts". The author reaches this conclusion because the ratio of the specific activity of diaphyseal bone to that of epiphyseal bone following administration of a single dose of radio-active calcium (Ca^{45}) or radio-active phosphorus (P^{32}) did not remain constant in growing rats over a sixty-day period but increased from a figure below unity to one above unity. The experimental findings do not justify the conclusion reached. From the standpoint of logic, a changing ratio may indicate a change in either the denominator, the numerator, or both. In the case of the author's experiment, the ratio could be affected by (1) selective mobilization of the isotope deposited from one area and not from another (for example, trabecular *versus* cortical bone) and the subsequent excretion of the isotope by way of the kidney or bowel—this is not "redistribution" in the commonly accepted meaning of the term; (2) by the physical displacement with growth of the metaphyseal bone into the diaphyseal region—this also does not constitute "redistribution"; (3) by dilution of the isotope with the deposition of new matrix in the area (thus affecting the activity per unit ash weight of bone)—this also does not constitute "redistribution"!

My colleagues and I have discussed the problem of "redistribution" at length. It is a difficult concept to prove by experimental means. We feel that the best method would probably be by means of serial radioautographs (following injection of a radio-active isotope, such as Ca^{45}) during the process of growth. Dr. Aub, of Boston, has approached the problem by means of alizarin and has shown that, immediately after administration, the alizarin is deposited in the trabecular but not in the cortical bone. At a later date, no traces of alizarin could be found in the trabeculae, but a line appeared in the cortex. We feel that sounder conclusions can be drawn from this experiment than from Bauer's experiment based on changing ratios.

Another criticism of Bauer's work is based on the technique of pooling the bone samples to determine their specific activity. It is our opinion, based on a series of similar experiments, that, if the author had made individual counts on the separate bone fragments, the variations between determinations would have been greater in some cases than the differences between groups. The statistical error of the counting technique is undoubtedly less than differences in metabolism between individual animals. The author offers no proof of statistical differences between the groups, and it is not clear how this could be done.

Robert D. Ray, M.D.
Head, Division of Orthopaedic Surgery
University of Washington
School of Medicine
Seattle 5, Washington.

May 3, 1954.

CORRECTION

An error appeared in the article on "Acrylic Prosthesis Replacing Lower End of the Femur for Benign Giant-Cell Tumor" by Dr. George L. Kraft and Dr. Daniel H. Levinthal as published in the April issue of *The Journal*.

On page 368 the legend under Fig. 1-A and Fig. 1-B should have read "Anteroposterior and lateral roentgenograms of the right femur, showing a benign giant-cell tumor which extends down to the cortical bone of the articulation. A pathological fracture is evident." The last line on the page should have been omitted.

It is suggested that this correction be made by the reader in his April issue.

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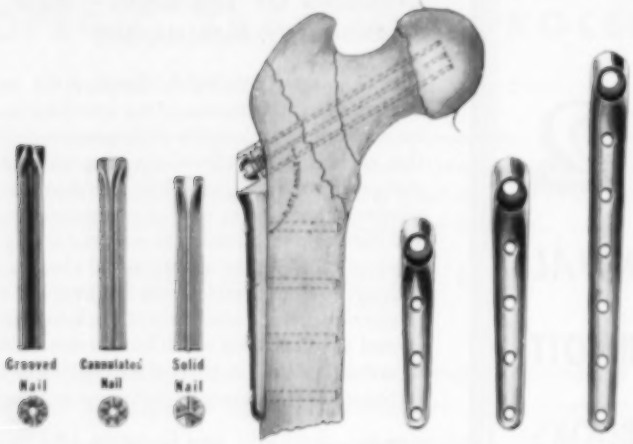

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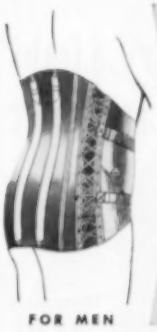

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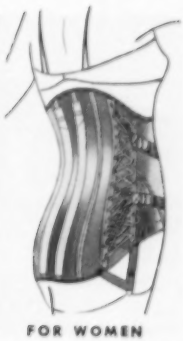

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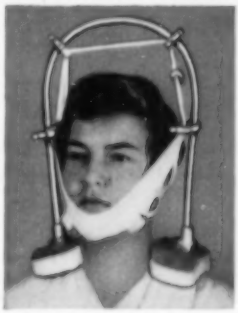

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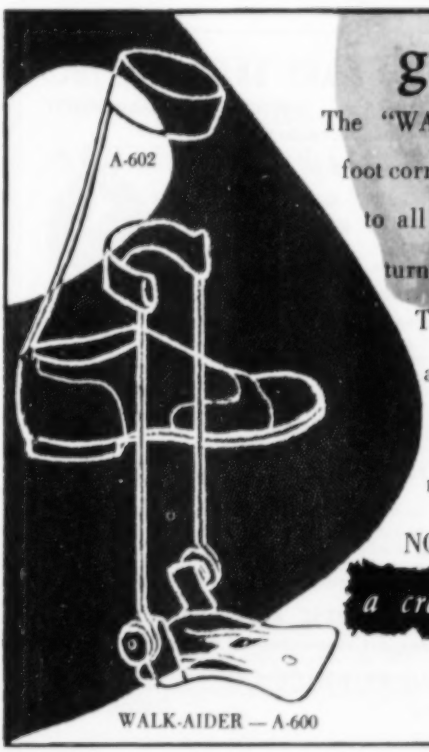

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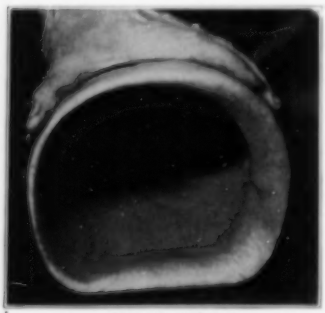

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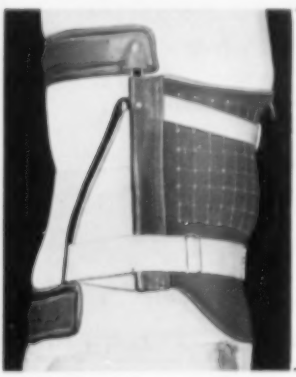

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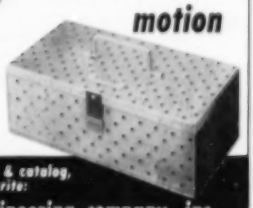

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